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The Sablefish

Marine Fisheries REVIEW

On the cover: Live sablefish, *Anoplopoma fimbria*, photographed aboard the *Seaview* by F. W. Hipkins. See the article beginning on page 1.

Articles — *49(1), 1987*

Biology of Eggs, Larvae, and Epipelagic Juveniles of Sablefish, *Anoplopoma fimbria*, in Relation to Their Potential Use in Management — *Arthur W. Kendall, Jr.*, and *Ann C. Matarese* 1

Movements of Brown Shrimp, *Penaeus aztecus*, and Pink Shrimp, *P. duorarum*, Relative to the U.S.-Mexico Border in the Western Gulf of Mexico — *Peter F. Sheridan, Frank J. Patella, Jr., Neal Baxter*, and *Dennis A. Emiliani* 14

Special Section
The Cooperative MEXUS-Gulf Research Program: Summary Reports for 1977-85

Preamble 20

MEXUS-Gulf Shrimp Research, 1978-84 — *Edward F. Klima, Refugio Gmo. Castro Melendez, Neal Baxter, Frank J. Patella, Terry J. Cody*, and *Loretta F. Sullivan* 21

MEXUS-Gulf Demersal Fish Research, 1978-85 — *Elmer J. Gutherz* 31

MEXUS-Gulf Coastal Pelagic Fish Research, 1977-84 — *Eugene L. Nakamura* 36

MEXUS-Gulf Ichthyoplankton Research, 1977-84 — *William J. Richards* 39

MEXUS-Gulf Remote Sensing and Technology Research, 1977-84 — *Andrew J. Kemmerer, Thomas D. Leming*, and *Walter F. Gandy* 42

MEXUS-Gulf Sea Turtle Research, 1977-85 — *Frederick H. Berry* 50

Departments

NOAA/NMFS Developments 52

Foreign Fishery Developments 61

Publications 77

U.S. DEPARTMENT OF COMMERCE

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Biology of Eggs, Larvae, and Epipelagic Juveniles of Sablefish, *Anoplopoma fimbria*, in Relation to Their Potential Use in Management

ARTHUR W. KENDALL, Jr., and ANN C. MATARESE

ABSTRACT—Recent studies on sablefish, Anoplopoma fimbria, *early life history have shown that they spawn pelagic eggs in winter near the edge of the continental shelf. The eggs float deeper than 200 m and probably require 2-3 weeks to develop. Shortly after hatching, the larvae seem to swim to the surface and grow quickly (up to 2 mm per day) as part of the neuston during spring. There is no marked transition from larvae to juvenile, but by summer the young-of-the-year fish are found at the surface in inshore waters. This is a review of the studies on which these conclusions are based and an evaluation of how early life history information might be used to improve management of the fishery.*

Introduction

Sablefish, *Anoplopoma fimbria* (also known as "blackcod"), are a moderately sized (length to about 100 cm) semidemersal fish mainly of the outer continental shelf and upper slope of the North Pacific Ocean. This fish and the skilfish, *Erilepis zonifer*, another North Pacific resident, are the only members of the cottoid family Anoplopomatidae.

Sablefish occur widely along the Asian coast from Sagami Bay north along the Japanese coast to Cape Navarin, and along the North American coast from the northeastern Bering Sea south to Baja California (Sasaki, 1985). Along the west coast of the United States sablefish have been the target of both foreign and domestic fisheries since the end of the last century where they are caught by trawl, longline, and trap. In 1973, the United States imposed regulations on foreign fisheries and initiated intense discussions on sablefish biology, assessment, and regulation (Sasaki, 1985). It appears that sablefish in the U.S. and Canadian exclusive economic zones are now fully utilized, although most of the products are exported. High levels of incidental catch of sablefish in other fisheries have forced some to cease operations before the quotas of the target species have been reached.

Although various aspects of sablefish biology and the fishery have been studied (e.g., Bell and Gharrett, 1945; Phillips, 1958; Shubnikov, 1963; Kodolov, 1968, 1976; Sasaki, 1985), until recently little was known about sablefish during their first few months of life. Knowledge of the early life history of sablefish has potential to help management of the fishery in several ways, including improving the methods for stock assessment and measurement of year-class strength. Understanding factors influencing survival of eggs and larvae may lead to early forecasts of recruitment several years before the year class enters the fishery.

New information on sablefish early life history has resulted mainly from several ichthyoplankton sampling programs from the Bering Sea to northern California and from experimental work at Oregon State University, Corvallis, and the Pacific Biological Station in Nanaimo, B.C. It is now known that sablefish spawn pelagic eggs in winter near the edge of the continental shelf. The eggs float deeper than 200 m and probably require 2-3 weeks to develop. At hatching, the larvae seem to swim immediately to the surface and grow quickly (up to 2 mm per day) as part of the neuston during spring. There is no marked transition from larvae to juvenile, but by summer the young-of-the-year fish are found at the surface in inshore waters. This paper is a review of the studies on which these conclusions are based and an evaluation of how early life history information might be used to improve management of the fishery.

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Description of Eggs and Larvae

The early life history stages of sablefish are incompletely described in the literature. Sablefish eggs have been reported mainly from deep (>200 m) plankton tows, although they have not been adequately described or illustrated (Thompson, 1941; Mason et al., 1983b). Sablefish larvae[1] larger than 9.0 mm SL and juveniles have been reported in the literature since Brock (1940) first described four postflexion larvae (21-33 mm TL) collected from surface waters off Oregon and noted their unique coloration (blue-green on the dorsal surface and silvery on the ventral surface) and the large size of the pectoral fin (about one-third the length of the body). Sablefish larvae (11.3-30.2 mm TL, n=16) collected from surface waters near the

[1]Lengths of sablefish larvae are described using one of the following body measurements: Notochord length (NL) = A straight-line measurement from snout tip to notochord tip prior to development of the caudal fin, standard length (SL) = A straight-line measurement from snout tip to posterior margin of hypural element, and total length (TL) = A straight-line measurement from most anterior point to most posterior point of the fish.

Aleutian Islands were described and illustrated by Kobayashi (1957). Ahlstrom and Stevens (1976) briefly described 443 larvae (9.0-33.0 mm SL) collected in neuston samples from off Washington and Oregon and illustrated a series of five larvae (11.7-33.0 mm SL).

Based on the occurrence of sablefish eggs in slope waters off British Columbia in plankton tows to deeper than 400 m (Mason et al., 1983a, b), we made 12 special deep-water plankton tows during March 1984 along the continental slope off the coasts of Washington, Oregon, and northern California (Table 1). These deep-water tows (mean depth = 400 m), which were designed to collect the earliest life history stages (eggs and preflexion larvae <9.0 mm SL) of sablefish, produced the eggs and newly hatched larvae that are described and illustrated here, thus completing the description of sablefish development from egg through juvenile stage. Eggs and preflexion larvae were identified by considering a combination of characters (pigment, morphology, and number of myomeres). The largest larva collected in the deep-water tows (7.6 mm NL) was similar in these characters to the smallest larva collected in neuston tows (7.1 mm NL). Larvae larger than 8.0 mm NL, collected in surface waters, were identified by comparing our specimens with the smallest specimens illustrated by Kobayashi (1957) and Ahlstrom and Stevens (1976), 11.3 mm TL and 11.7 mm SL, respectively. Specimens less than 8.0 mm NL are generally less pigmented along the lateral body surface but have a similarly elongate body and gut, 61-66 myomeres, and relatively large eyes. Embryos in late-stage eggs and newly hatched larvae were matched to this series, and although they were less pigmented they were quite similar morphologically.

Table 1.—Summary of collection data for sablefish eggs and larvae taken at deep plankton stations off Washington-Oregon in 1984.

Station	No. of eggs	No. of larvae	Latitude (°N)	Longitude (°W)	Date	Sample depth (m)
G002B	2	4	48°00.9′	125°56.0′	12 March	390
G012B	0	1	47°21.5′	125°43.0′	13 March	402
G019B	1	4	46°40.5′	124°59.0′	15 March	389
G044B	1	0	45°19.0′	124°46.0′	20 March	403
G122B	1	0	40°00.1′	124°51.0′	4 April	404

Eggs

Near-spawning ovarian eggs (Fig. 1) of sablefish are translucent and 1.0-1.2 mm in diameter (Mason et al., 1983b). Mason et al. (1983b) characterized developing eggs as pelagic, 1.8-2.2 mm in diameter with a smooth chorion, no oil globules, a narrow perivitelline space, and an embryo that remains unpigmented until later developmental stages. Sablefish eggs are unlike those of most other cottoids, which are demersal, about 1-2 mm in diameter, and have a single oil globule.

Eggs obtained from the deep plankton tows along the continental slope off Washington, Oregon, and northern California (diameter range 1.80-2.09 mm), and eggs stripped, fertilized, and reared under the supervision of D. F. Alderdice[2] at the Pacific Biological Station (diameter range 2.07-2.11 mm) compare favorably with the description by Mason et al. (1983b) and are similar to some collected off southeastern Alaska (Table 2). Identification of eggs from the plankton is thus possible based on the combination of the size of the eggs (1.8-2.2 mm), smooth chorion, narrow perivitelline space, lack of oil globules, myomere count (61-66), and lack of pigment on late-stage embryos which have a long gut (>50 percent body length). The embryos and newly hatched larvae fit into a series leading to larger larvae with diagnostic meristic characters.

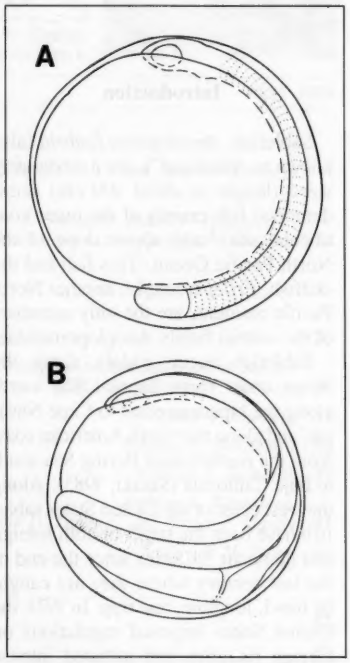

Figure 1.—Eggs of sablefish: A) Late middle-stage egg (283 hours) reared at Pacific Biolological Station, Nanaimo, B.C.; B) late-stage egg collected off the Washington coast, March 1984.

Larvae

Newly hatched larvae (5.0-6.0 mm NL) are unpigmented (Fig. 2A). Pigment first appears in larvae larger than 6.0 mm NL when the eyes are pigmented. Melanophores, which appear along the entire dorsal surface of the gut when larvae are about 6.5 mm SL, are larger and more concentrated posteriorly (Fig. 2B). Pigment also appears along the ventral body midline with several melanophores immediately posterior to the anus and a short series along the posteriormost 10 or so myomeres. Along the dorsal midline, melanophores extend from about midway along the postanal body to near the last myomere. Pigment continues to increase along the dorsal midline in larvae larger than 6.5 mm SL, extending from the head and nape to the last myomere, but the short series of ventral midline melanophores does not appear to increase anteriorly

[2]Alderdice, D. F., J. O. T. Jensen, and F. P. J. Velsen. Preliminary trials on incubation of sablefish eggs (*Anoplopoma fimbria*). Pac. Biol. Stn., Nanaimo, B.C. Unpubl. manuscr., Jan. 1986.

Table 2.—Collections of sablefish eggs, larvae, and epipelagic juveniles.

Area of sampling	Dates of sampling	Size range ($\bar{x}$) (mm)	Number	Gear[1]	References
Eggs					
Cape St. James, Queen Charlotte Island	Winter 1937, 1941	(2.097)	80	Plankton	Thompson, 1941
Off British Columbia	9 January-20 April 1980	1.8-2.2	43[2]	Bongo	Mason et al., 1983b
S.E. Alaska	19-25 January 1984, 2 February 1985	1.8-1.9	>68	Bongo	NWAFC files[3]
WA-OR-CA	12-28 March 1984	1.8-2.09 (2.00)	5	Bongo	NWAFC files[4]
Larvae and juveniles					
Monterey Bay		75	1	(at surface)	Gilbert, 1915
Off Oregon	23-25 May 1939	21-35 SL	4	Dipnet	Brock, 1940
Aleutians (Attu-Umnak)	8 July-13 August 1955-56	11.3-30.2 TL 25.4 BL	18	Neuston	Kobayashi, 1957
Aleutian Islands, Bering Sea, Gulf of Alaska	12 June-13 August 1955-69	5.6-43.5	164	Neuston	Hokkaido University, 1957a,b, 1958, 1959a,b, 1960a,b, 1961, 1964, 1968, 1969, 1970
So. Calif./Baja Calif.	June, July 1964-68	66-149 SL	650	Purse seine	Mitchell and Hunter, 1970
Bering Sea	June-August 1970-79	Not given	382	Neuston	Haryu et al., 1985
Most lat. 46°00'N, long. 121°00'W; some OR and CA	May 1972	9.0-32.5 SL	468	Neuston	Ahlstrom and Stevens, 1976
Off Oregon	March 1972-75, April 1972, 1973	Not given	16[5]	Bongo	Richardson et al., 1980
Bering Sea lat. 52° -60°N, long. 166° -179°W	1 June-23 July 1979	11.0-25.2 (15.5) SL	306	Neuston	Text foonote 10
WA-OR-CA	4 April-13 May 1980	6.3-37.0 (14.2) SL	621	Neuston	Text footnote 6
Off British Columbia	11 March-20 April 1980	6-9 (most 7-8) TL	55	Bongo	Mason et al., 1983b
Gulf of Alaska	19-22 April 1981	8.1-11.6 (9.9) SL	2	Neuston	Bates and Clark[6]
Gulf of Alaska off Kodiak Island	19 June-9 July 1978	11.0-26.2 (19.1) SL	19	Neuston	Kendall and Dunn, 1985
WA-OR-CA	9 May-2 June 1981	10.5-38.0 (23.43) SL	24	Neuston	Text footnote 4
Line "P", 70 and 175 km offshore	Late March 1982	9-10 TL	4	Neuston	Mason et al., 1983b
Gulf of Alaska	22-30 May 1982	8.8-10.0 SL	2	Bongo	NWAFC files[4]
WA-OR-CA	3-30 May 1982	10.7-41.2 SL	77	Neuston	NWAFC files[4]
WA-OR-CA	24 April-8 May 1983	7.2-38.0 (16.04) SL	259	Neuston	Text footnote 8
		10.4-12.1 (11.43) SL	4	Bongo	
Gulf of Alaska	22-28 May 1983	9.0-20.3 (14.63) SL	227	Neuston	NWAFC files[4]
WA-OR-CA	12-28 March 1984	7.1-28.5 (11.16) SL	202	Neuston	NWAFC files[4]
		5.6-8.3 (6.93) SL	14	Bongo	
Off Vancouver Island	16 April-10 May 1984	8 TL-38 FL (16.6)	722	Neuston	Shaw et al., 1985
S.E. Alaska	23-26 May 1985	10.4-21.1 SL	46	Neuston	NWAFC files[3]
	7, 14 July 1985	21.1-30.9 SL	3	Neuston	NWAFC files[3]

[1]Bongo: A paired plankton net usually 50-70 cm in diameter towed obliquely from a specified depth (e.g., 400 or 200 m) to the surface. Neuston: A plankton net of various dimensions towed at the surface.
[2]Occurrences in 303 samples.
[3]Wing, B. L. Auke Bay Lab. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, P.O. Box 210155, Auke Bay, AK 99821. Unpubl. data.
[4]Kendall, A. W., Jr., and J. B. Clark. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. Unpubl. data.
[5]Occurrences in 306 samples.
[6]Bates, R. D., and J. B. Clark. 1983. Ichthyoplankton off Kodiak Island and the Alaskan Peninsula during spring 1981. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 83-09, 105 p.

(Fig. 2C). Specimens larger than 7.0 mm NL collected in neuston net tows have pigment along both the dorsal and ventral midlines, and possess some lateral pigment about midbody (Fig. 2D).

Sablefish change gradually in morphology between notochord flexion (10-16 mm SL) and about 35 mm SL when they can be considered epipelagic juveniles. The larvae are elongate and heavily pigmented (Fig. 3). They develop remarkably large pectoral fins that are especially heavily pigmented near the distal margin of their blades. The eye is large and, in contrast to larvae of most other scorpaeniforms, there are no head spines. The head becomes relatively longer and the body deeper (more robust) as the larvae grow (Table 3). The size of the eye, and the preanal length grow in proportion to length of smaller larvae, but increase in proportion slightly in larger larvae. A morphological feature that appears to be diagnostic for sablefish larvae is the unique shape of the anus which curves ventrad in specimens larger than 6.0 mm SL. There is no marked morphological transformation from the larval to juvenile stage, probably because both stages are epipelagic and have evolved a form adapted to this habitat.

Since the literature (e.g., Kobayashi, 1957), indicates that sablefish larvae are often measured using total length, we performed a simple linear regression using 30 sablefish larvae (6.2-26.4 mm SL) to compare total length and standard length. The following equation resulted:

$$TL = (-1.668) + 1.279\ (SL)$$
$$r = 0.999.$$

Sablefish larvae may be confused with other heavily pigmented larvae such as those of sauries, *Cololabis saira*, in the southern part of their range, and with those of greenlings (Hexagrammidae), cryptacanthodids, *Lyconectes/Delolepis*, and prowfish, *Zaprora silenus*,

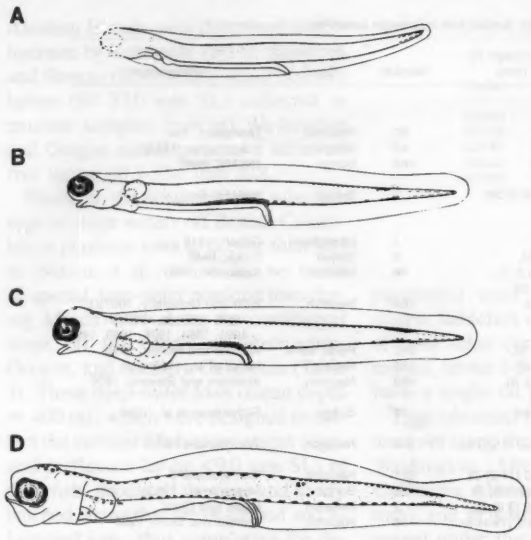

Figure 2.—Early larvae of sablefish: A) 5.6 mm SL; B) 6.5 mm SL; C) 6.9 mm SL; D) 8.8 mm SL. A-C were collected off the Washington coast in March 1984 and D was collected in a neuston tow in the Bering Sea in 1977.

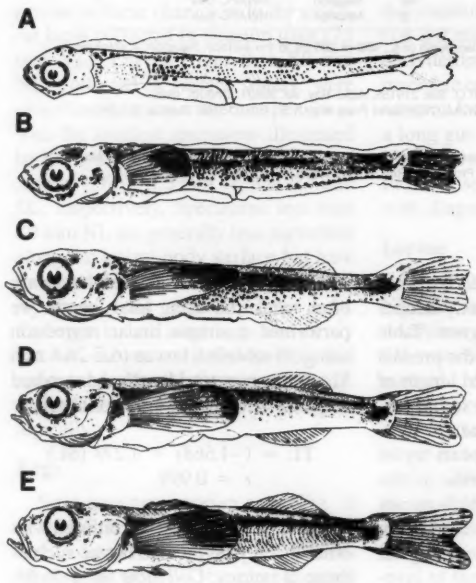

Figure 3.—Later larvae of sablefish from Ahlstrom and Stevens (1976): A) 11.7 mm SL; B) 13.8 mm SL; C) 18.6 mm SL; D) 23.0 mm SL; E) 33.0 mm SL.

Table 3.—Measurements and body proportions (mm) of sablefish larvae. Mean and standard deviation given for each body proportion are expressed as percentages of notochord length (NL) or standard length (SL)[1].

Notochord/ standard length	Head length	Eye dia.	Snout to anus length	Body depth at pectoral fin base	Body depth at anus
Preflexion larvae					
5.6	0.9		3.3	0.4	0.4
6.5	0.9	0.5	3.4	0.4	0.4
6.6	1.1	0.5	3.6	0.6	0.5
6.6	0.9	0.5	3.4	0.7	0.5
6.8	1.1	0.5	3.5	0.7	0.5
6.9	1.1	0.5	3.6	0.7	0.4
7.6	1.2	0.5	3.9	0.8	0.4
7.6	1.2	0.5	4.1	0.8	0.5
Summary of Preflexion					
Sample size	8	7	8	8	8
Mean (% NL)	15.5	7.2	53.3	9.3	6.7
S.D.	1.1	0.4	2.6	1.7	0.9
Flexion larvae					
10.3	1.9	0.8	5.5	1.0	0.9
10.8	2.3	0.8	6.0	1.4	1.2
13.3	2.3	0.8	6.6	1.4	1.3
13.5	2.7	1.0	7.5	1.7	1.5
13.6	2.7	1.0	7.2	1.5	1.5
14.5	3.0	1.0	8.1	1.7	1.6
15.3	3.2	1.2	8.1	2.0	1.7
15.4	3.2	1.1	8.0	1.9	1.7
15.6	3.3	1.1	8.1	1.9	1.8
16.1	3.4	1.1	8.2	1.9	1.8
Summary of Flexion					
Sample size	10	10	10	10	10
Mean (% NL)	20.2	7.2	53.1	11.8	10.8
S.D.	1.3	0.5	2.1	1.1	0.9
Postflexion larvae					
16.1	3.8	1.3	8.7	2.5	2.2
16.5	4.2	1.3	9.3	2.6	2.4
18.5	4.8	1.6	10.5	2.8	2.7
18.6	5.0	1.6	11.0	3.2	2.7
19.4	4.9	1.4	12.0	2.9	2.6
19.6	5.2	1.6	11.1	2.9	2.7
21.4	5.3	1.8	12.1	3.2	3.0
25.3	6.6	1.9	13.8	3.8	3.6
26.4	6.9	1.9	14.5	4.3	3.6
26.6	6.9	2.1	15.5	4.2	3.8
Summary of Postflexion					
Sample size	10	10	10	10	10
Mean (% SL)	25.7	8.0	56.9	15.5	14.1
S.D.	1.0	0.5	2.4	0.8	0.4

[1]Measurements were made following definitions in Matarese et al. (1981), except NL which was measured from the snout tip to notochord tip prior to development of caudal fin.

throughout their range. However, the enlarged, pigmented pectoral fins are diagnostic of sablefish larvae.

Spawning Season

Mason et al. (1983b) reviewed and augmented information on time of spawning derived from gonadal maturity observations of adults. In various parts of the North Pacific Ocean spawning seems to occur from late fall through early spring. Spawning seems to take place earlier in the year in the southern part of the range (December off California) and becomes progressively later

toward the north (May off the Aleutian Islands). The gonadal cycle of females from off British Columbia indicated a rather short spawning season from January to March with a distinct peak in mid-February.

Boehlert and Yoklavich (1985) estimated the birth dates of specimens used for their larval growth study and found, assuming a 13-day incubation period and an equal time before first feeding when otolith increments may begin to be laid down, that peak spawning off Washington and Oregon would have occurred in early March. These data may be biased toward spawning later in the season, because the neuston nets used allow larger specimens to escape, and the sampling was done when specimens from spawning earlier in the year would no longer have been vulnerable to capture.

Developmental Rates

Egg Incubation Period

Based on maximum seasonal catches of eggs in February and those of larvae in April, Mason et al. (1983b:2129) suggested an incubation period "exceeding several weeks." Based on an empirical relationship between egg size and incubation time, Boehlert and Yoklavich (1985) suggested that sablefish, with a 2 mm egg, would have an incubation time of 13 days. The effect of development at considerable depths (300-400 m) and at prevailing incubation temperatures of less than 6°C (Mason et al., 1983b) on this relationship is unknown. Recent rearing experiments on sablefish eggs held at 4.0°C yielded an estimate of time from fertilization to 50 percent hatch as 400.9 hours (16.7 days)^2.

Larval Growth

Since sablefish spawn during a fairly restricted season (mainly January-February) off British Columbia it has been possible to estimate growth rate by observing the length frequency of young-of-the-year juveniles. This method led to the statement that "young of the year are inshore in July at 5 cm and grow to 28 cm by November" (McFarlane and Beamish, 1983b). Nine juveniles (23-27 cm) captured in February had 270-350 daily growth increments on their otoliths indicating that they were close to a year old (Beamish et al., 1983). Mason et al. (1983a) stated concerning these same juveniles that "the pattern of daily growth suggested that the first month of growth occurs at spawning depths, then there is a period of approximately 4 months during which growth is irregular as the larval sablefish moves inshore in the surface waters." They did not tell what daily growth patterns led to these conclusions.

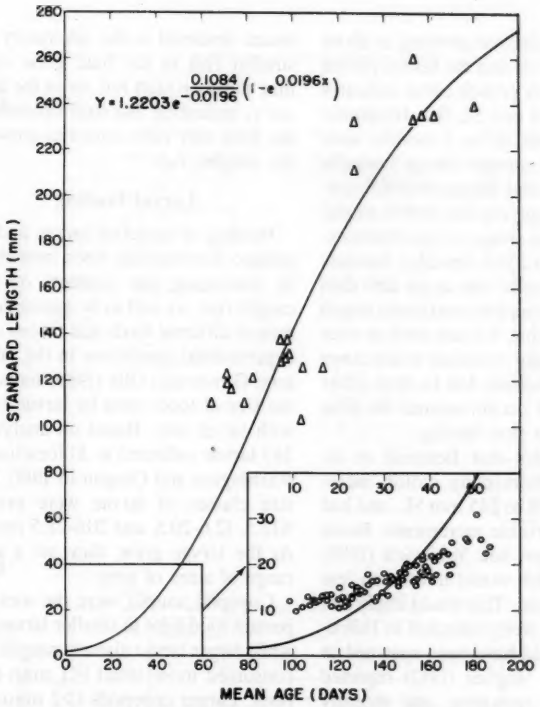

Figure 4.—Growth rate of young sablefish from Boehlert and Yoklavich (1985).

Boehlert and Yoklavich (1985) studied growth during the first 6 months of life in more detail using daily growth increments on otoliths of 105 field-caught specimens, validated by data from three laboratory-held specimens. They found growth of fish 9.8 to 41.2 mm SL could be described by the straight line:

$$(SL) = 0.375 \text{ (age, d)} + 5.27$$
$$n = 71,\ r^2 = 0.838.$$

Growth of fish 102.8 to 259.6 mm SL could be described by the straight line:

$$SL = 1.469 \text{ (age, d)} - 0.926$$
$$n = 21,\ r^2 = 0.822.$$

Combining all data, for fish 9.8 to 259.6 mm SL, the best fit among the various models tried was to the Laird-Gompertz model:

$$L_t = L_0(A_0/\alpha)(1-\exp(-\alpha t))$$

where L_t = standard length at age t (d),

L_0 = initial length (y-intercept),

and A_0 and α are fitted parameters.

For the sablefish examined, L_0 = 1.2203, A_0 = 0.1084, and α = 0.0196 produced the best fit. This is a sigmoid curve showing slow growth up to 50 days and 25 mm SL, followed by an accelerating growth rate through the young-of-the-year juvenile stage (Fig.

4). The juveniles are growing at about 2 mm per day during the fastest period of growth. This growth curve indicates that the 111-148 mm SL fish Heyamoto (1962) estimated to be 6 months were actually much younger (about 3 months old). Boehlert and Yoklavich (1985) caution against applying this growth model outside the size range of specimens examined (9.8 to 259.6 mm SL), because it predicts a smaller size at age zero days and a lower asymptotic maximum length than is reasonable. It is unknown at what age the first daily increment is laid down in sablefish otoliths, but in most other fish studied it occurs around the time of hatching or first feeding.

The juveniles that Beamish et al. (1983) aged from daily otolith increments were 208 to 245 mm SL, and had 270-350 observable increments. Based on the Boehlert and Yoklavich (1985) curve these fish would have been less than 170 days old. This would imply that since the fish were collected in February, they would have been spawned in mid-summer. Hughes (1981) reported finding ripe, spawning, and recently spent sablefish in the water column above Gulf of Alaska seamounts in June. However, most other data indicate that sablefish spawn in late winter, so apparently the juveniles of Beamish et al. (1983) had grown much slower than those examined by Boehlert and Yoklavich (1985). A reasonable explanation for this discrepancy is that juvenile growth may be quite slow between summer when Boehlert and Yoklavich (1985) sampled their largest fish and February when Beamish et al. (1983) collected their fish, which were indeed approaching 1 year old.

Shenker and Olla (1986) held field-caught larvae and juveniles in the laboratory to examine the effects of various diets and feeding levels on their growth. They found that fish fed ad libitum grew up to 2.3 mm per day at lengths where the curve of Boehlert and Yoklavich (1985) predicts the fastest growth. This tends to substantiate the growth rate determined by the otolith aging technique, and indicates that epipelagic juvenile sablefish used in the growth study were finding sufficient prey in the field to sustain a growth rate near the maximum observed in the laboratory. The smaller fish in the field grew slower than those on high rations in the laboratory, indicating that food limitation in the field may have impeded growth of the smaller fish.

Larval Feeding

Feeding of sablefish larvae and epipelagic juveniles has been investigated by examining gut contents of wild-caught fish, as well as by examining effects of different foods and rations under experimental conditions in the laboratory. Grover and Olla (1986) found that the size of food eaten by larvae varied with larval size. Based on analysis of 267 larvae collected at 10 locations off Washington and Oregon in 1980, three size classes of larvae were evident: ≤12.5, 12.6-20.5, and 20.6-28.5 mm SL. As the larvae grew, they ate a wider range of sizes of prey.

Copepod nauplii were the most important food item in smaller larvae, and while larger larvae also ate nauplii, they consumed more small (<1 mm) copepods. Larger copepods (>2 mm) were more important in the diets of 20.6-28.5 mm SL larvae. Grover and Olla (1986) also found morphological evidence of starvation (empty shrunken guts, emaciated appearance) in small (<12.5 mm SL) larvae at one station. They deduced that a shortage of copepod nauplii at this station had caused the larvae to become emaciated.

Grover and Olla (In press) compared the diets of the same three size classes of larvae caught in 1980 with those caught in 1983, an El Niño year (Fig. 5). Sablefish larvae occur off Oregon at a transitional time of year (spring) between the winter plankton assemblage which originates to the south, and the summer assemblage which originates to the north. During the El Niño year, the winter assemblage dominated through spring and into July (Miller et al., 1985). Zooplankton density was reduced, possibly as low as 30 percent of a non-El Niño year. Although there was no evidence of starvation in 1983, sablefish larvae had more small copepods in their diet than in 1980. This could have impacted growth because of the lower caloric value, and an increase in energy spent in capturing and handling the smaller copepods.

Laboratory studies with epipelagic sablefish have shown them to be hardy and fast growing (Shenker and Olla, 1986). Two live prey species (brine shrimp and a mysid shrimp) were fed to juveniles in individual tanks at rations of 10, 20, and 30 percent body weight per day and also ad libitum. The mysids were more nutritious. Growth rates for fish fed on mysids varied from 0.90 mm/day at 10 percent ration to 2.24 mm/day when fed ad libitum. Growth rate in length decreased linearly with increase in length, although weight increased as a power function of increasing length. The smaller fish (40 mm SL) increased by 13-15 percent body weight per day, while 110 mm SL fish increased by 5-7 percent body weight per day. Sablefish are among the fastest growing epipelagic juvenile fish studied to date (Shenker and Olla, 1986).

Distribution of Eggs and Larvae

Vertical Distribution

No systematic study has been conducted to investigate the vertical distribution of sablefish eggs and larvae at sea. However, the following inferences can be drawn from the collection depths of the eggs and larvae during surveys and from limited laboratory work: Sablefish eggs have been found to be pelagic, but occur deeper than 200 m. Toward the end of the yolk-sac stage, the larvae move to the surface of the sea where they remain as part of the neuston from about 10-80 mm SL.

Data on vertical distribution of sablefish eggs obtained from our deep-water plankton collections in 1984 agree with previous studies (Thompson, 1941; Mason et al., 1983b). Eggs and newly hatched larvae, previously unknown in samples from the upper 200 m of the water column, were collected when the sampling depth was increased to 400 m. The presence of eggs at depths greater than 200 m coincides with the available data on the bathymetric distribution of mature sablefish (Sasaki, 1985). Presumably eggs are spawned and hatch at depths greater than 200 m as indicated

by our collection of eggs and small (~7.0 mm SL) larvae exclusively in deep-water plankton tows. No sablefish eggs and only 5 larvae (<8.3 mm SL) were collected in the 125 bongo tows to 200 m that were taken on the same cruise. Larvae in neuston collections during this cruise were larger with a mean length of 11.16 mm SL.

Mason et al. (1983b) interpreted the absence of late-stage eggs and prevalence of newly hatched larvae (5-6 mm) in his samples as evidence for an egg descent into waters exceeding 400-500 m prior to hatching and maintenance of that deep position at least until hatching. Recent laboratory studies on sablefish egg density[2] lend some support to this hypothesis. The density of early- and middle-stage eggs was found to be about 1.0264. Based on this egg density, egg diameter, and the density of the ambient water (if spawning occurs around 500 m (d = 1.0269)), the eggs would rise in the water column to about 300 m during incubation. However, just prior to hatching, egg density was observed to increase, causing them to sink somewhat.

Small sablefish larvae (<10 mm SL) are rare in field collections. The few that have been taken have been almost exclusively in oblique plankton tows which have sampled to maximum depths of 400, 200, or 120 m (Table 3). There is no direct field evidence to support the contention that these larvae are deeper in the water column than 400 m (Mason et al., 1983b), although reared yolk-sac larvae have been found to be negatively buoyant[3]. From the presence of eggs deeper than 200 m and the presence of larvae larger than 10 mm SL in surface waters (see below), it is reasonable to suppose that as the yolk sac is absorbed the larvae swim to the surface. Newly hatched larvae of most fish are delicate and poorly represented in plankton catches, because they are extruded through the net meshes.

Larvae and early juveniles (10-80 mm SL) of sablefish appear to be obligate neustonic animals, i.e., they are found only at the surface of the sea. Larvae

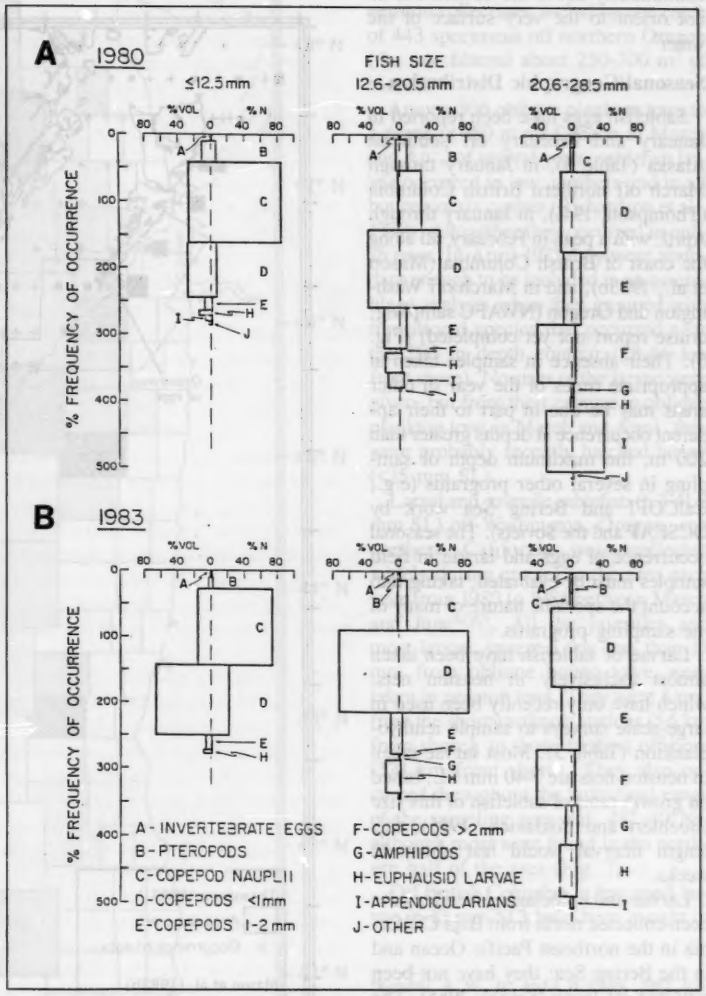

Figure 5.—Prey of larval sablefish, 1980 and 1983, from Grover and Olla (In press).

10-30 mm SL are frequently caught in neuston nets in spring, but are rarely seen in oblique tows, which are taken concurrently (Table 3). Juveniles up to 80 mm SL were taken in abundance in a larger neuston trawl, indicating that the upper size limit of fish in smaller neuston nets is caused by net avoidance of larger juveniles, not their departure from the surface layer (Shenker, 1984). Although juveniles larger than 50 mm SL have mainly been reported in nearshore waters (McFarlane and Beamish, 1983b), some up to 250 mm SL have been collected in offshore surface waters by small-mesh purse seine[4]. In the laboratory, sablefish 20-80 mm SL swim

[3]G. A. McFarlane, Pac. Biol. Stn., Nanaimo, B.C. V9R5K6. Personal commun., June 1986.

[4]W. Pearcy, Oregon State Univ., Corvallis, OR 97331. Personal commun.

continuously above the bottom but do not orient to the very surface of the water[5].

Seasonal/Geographic Distribution

Sablefish eggs have been reported in January and February off southeast Alaska (Table 3), in January through March off northern British Columbia (Thompson, 1941), in January through April, with a peak in February, all along the coast of British Columbia (Mason et al., 1983b), and in March off Washington and Oregon (NWAFC sampling; cruise report not yet completed) (Fig. 6). Their absence in samples taken at appropriate times of the year in other areas may be due in part to their apparent occurrence at depths greater than 200 m, the maximum depth of sampling in several other programs (e.g., CalCOFI and Bering Sea work by OCSEAP and the Soviets). The seasonal occurrence of eggs and larvae in field samples must be evaluated, taking into account the sporadic nature of many of the sampling programs.

Larvae of sablefish have been taken almost exclusively in neuston nets, which have only recently been used in large-scale surveys to sample ichthyoplankton (Table 3). Most larvae taken in neuston nets are 7-40 mm SL; based on growth rates of sablefish of this size (Boehlert and Yoklavich, 1985), this length interval would last about 12 weeks.

Larvae and epipelagic juveniles have been collected north from Baja California in the northeast Pacific Ocean and in the Bering Sea; they have not been reported off Japan (Sasaki, 1985). The following summarizes these collections.

Juveniles up to 149 mm SL were the fourth most abundant fish taken in purse seine sets that surrounded drifting masses of kelp off southern California and Baja California (Mitchell and Hunter, 1970). There, fish were collected in June and July and were seen by divers to remain some distance (0.75 to 8 m) from the kelp mass. In a May cruise off the Pacific coast of the United States, Ahlstrom and Stevens (1976) reported

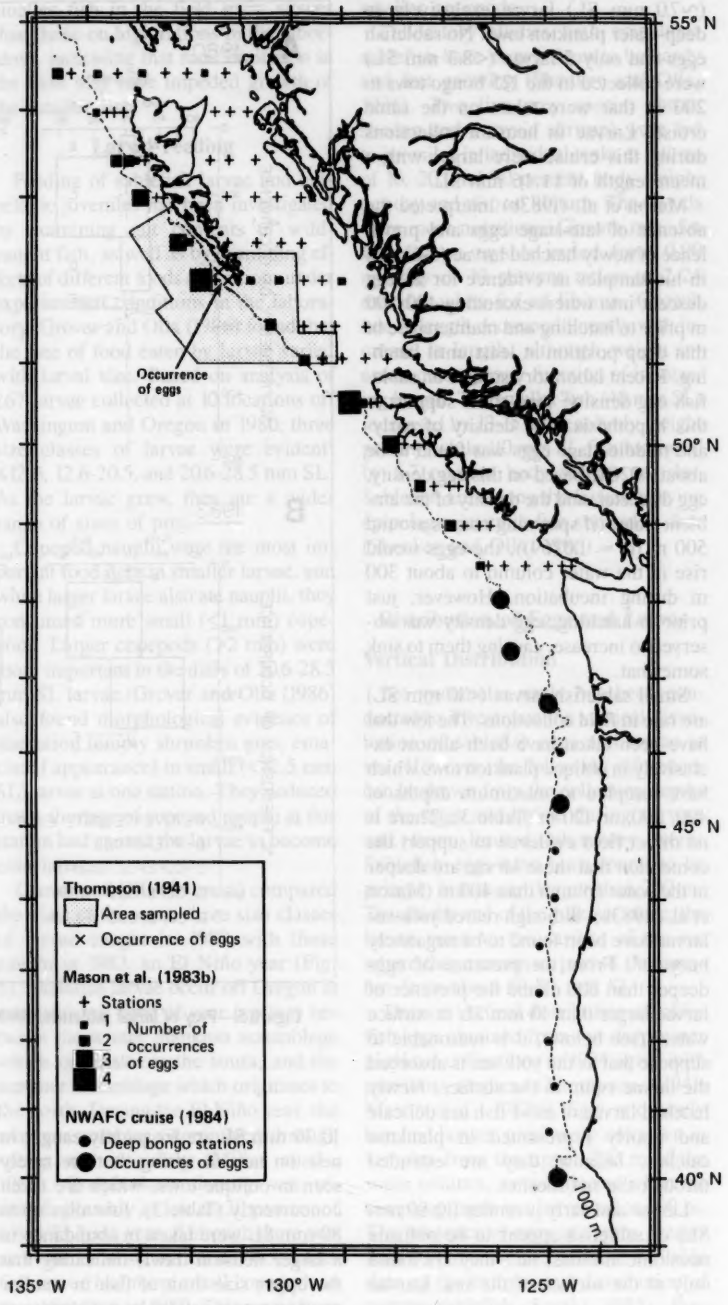

Figure 6.—Occurrences of sablefish eggs based on Thompson (1941), Mason et al. (1983b), and NWAFC sampling.

[5]B. L. Olla, Oregon State Univ., Newport, OR 97365. Personal commun.

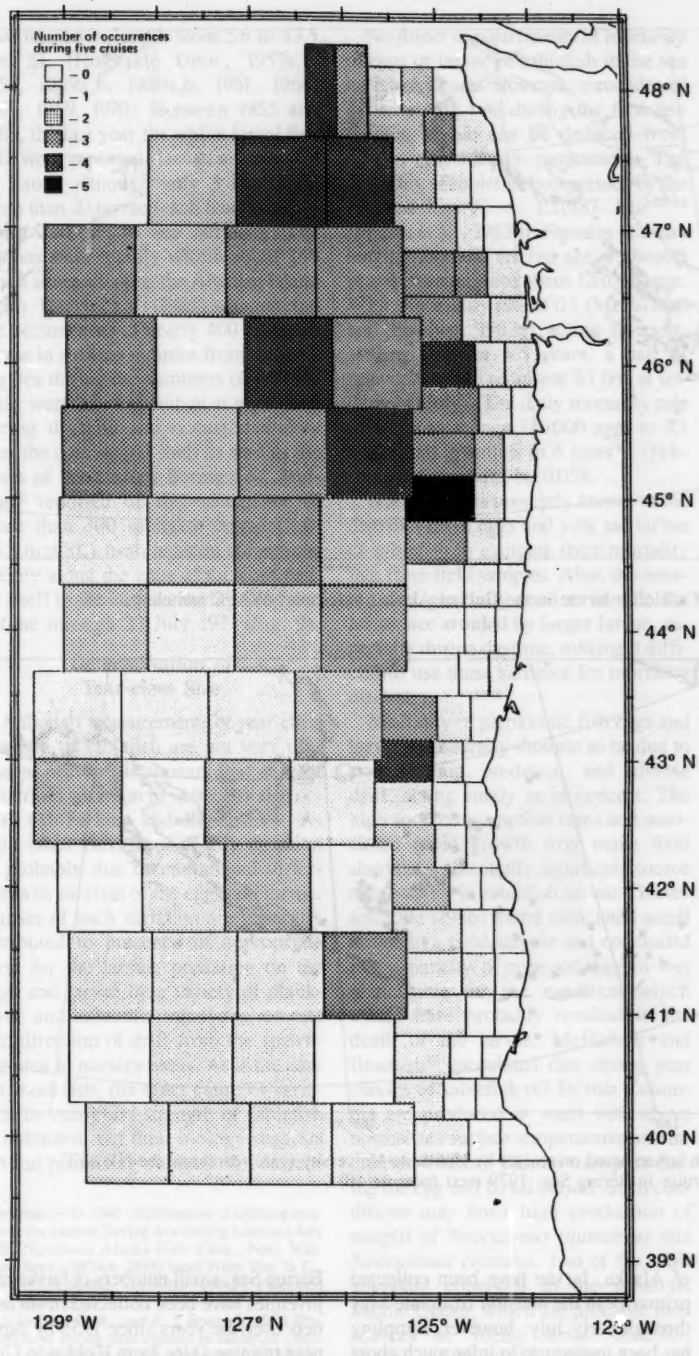

Figure 7.—Occurrences of sablefish larvae off the U.S. west coast.

larvae (9.0-32.5 mm SL) in 7 of 105 neuston collections, including one catch of 443 specimens off northern Oregon (the tow filtered about 250-300 m^3 of water).

Among 306 oblique plankton tows to a depth of 150 m off Oregon in March and April of several years, sablefish larvae occurred in low numbers and in all but one of six cruises (Richardson et al., 1980). Altogether they occurred in only 16 tows. In April 1973 they were abundant enough to be included in an assemblage analysis when they grouped with transitional species that occurred near the 200 m depth contour (28-46 km from shore). No sizes of the larvae were given, but from their capture in oblique plankton tows in March and April, they were probably recently hatched larvae (<15 mm SL).

Larval and juvenile sablefish (6.3-41.2 mm SL) off Washington, Oregon, and northern California were collected widely during cruises to the area each year from 1980 to 1984 between March and June[6,7,8,9]. All the juveniles and most larvae, except a few less than 13 mm from oblique bongo tows, were taken in neuston tows. They were found from the shorewardmost stations (5.6 km from shore), to those farthest offshore (370 km from shore). They also occurred throughout the latitudinal range of the sampling area (lat. 48°-40°N), although most were found in the northern half of the area (Fig. 7).

Off British Columbia, a few small larvae (6-10 mm SL) have been caught in

[6]Kendall, A. W., Jr., and J. B. Clark. 1982. Ichthyoplankton off Washington, Oregon, and northern California April-May 1980. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 82-11, 44 p.

[7]Clark, J. B. 1984. Ichthyoplankton off Washington, Oregon, and northern California April-May 1980. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 84-11, 46 p.

[8]Clark, J. B., and A. W. Kendall, Jr. 1985. Ichthyoplankton off Washington, Oregon, and northern California April-May 1983. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 85-10, 48 p.

[9]Kendall, A. W., Jr. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. Unpubl. data.

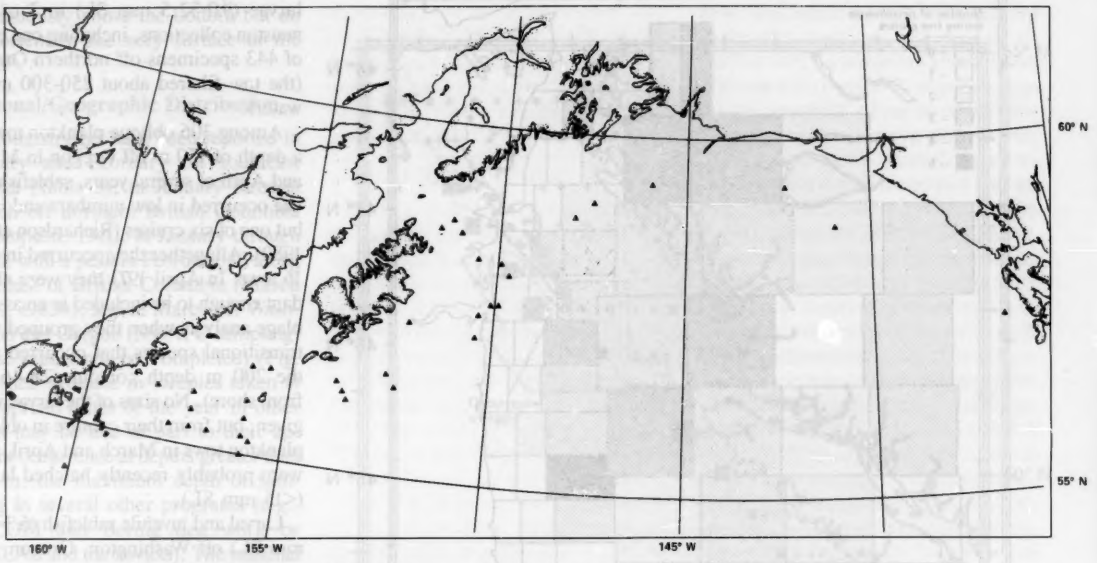

Figure 8.—Occurrences of sablefish larvae in the Gulf of Alaska, based on NWAFC sampling.

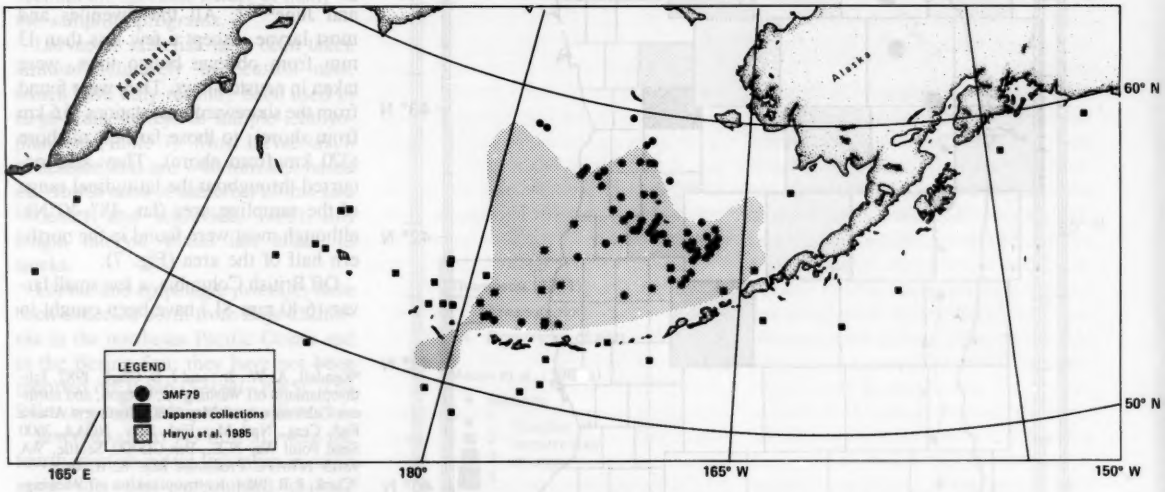

Figure 9.—Occurrences of sablefish larvae based on cruises by Hokkaido University (var. years) and the NWAFC cruise in Bering Sea, 1979 (text footnote 10).

oblique plankton tows in March and April (Mason et al., 1983b) and larger larvae (8-38 mm) were taken mainly at stations between the 200- and 2000-m depth contours in neuston tows in April and May (Shaw et al., 1985). In the Gulf of Alaska, larvae have been collected primarily in the neuston from late May through early July; however, sampling has been inadequate to infer much about their distribution (Table 3, Fig. 8).

Near the Aleutian Islands and in the Bering Sea, small numbers of larvae and juveniles have been collected in surface nets over the years since 1955 by Japanese training ships from Hokkaido University (Fig. 9). Catches have occurred from 12 June to 13 August and larvae

have ranged in length from 5.6 to 43.5 mm SL (Hokkaido Univ., 1957a,b, 1958, 1959a,b, 1960a,b, 1961, 1964, 1968, 1969, 1970). Between 1955 and 1969, the last year for which larval fish data were reported, larvae occurred in 47 hauls, although only 3 hauls had more than 10 larvae (each haul sampled about 790 m^2 of sea surface). The catches were mainly within about 240 km of shore all along the Aleutian Island chain. Haryu et al. (1985) summarized the occurrences of nearly 400 sablefish larvae in surface samples from the Bering Sea during the summers of 1970-78. They were more abundant at night than during daytime and occurred widely over the continental shelf as well as the basin of the eastern Bering Sea. Walline[10] reported on the occurrence of more than 300 sablefish larvae (11.0-25.5 mm SL) from neuston collections mainly along the edge of the continental shelf in the eastern Bering Sea from 1 June through 23 July 1979 (Fig. 9).

Determination of Year-class Size

Although measurements of year-class strength of sablefish are not very precise at present, it appears that at least a fourfold variation in year-class size occurs (McFarlane and Beamish[11]). As with other fish, most of this variation is probably due to interannual differences in survival of the eggs and larvae. Causes of such variation are generally attributed to presence of appropriate food for the larvae, predation on the eggs and larvae by a variety of planktonic and nektonic organisms, or rate and direction of drift from the spawning area to nursery areas. As is the case for most fish, the exact cause of variation in year-class strength of sablefish is unknown, but their biology suggests several promising avenues of research.

No direct measurements of mortality of eggs or larvae of sablefish in the sea have been made. However, some idea of the mortality rate during the first few months of life can be deduced from several life history parameters. The fecundity of sablefish is expressed by the relationship $F = 1.11987\ FL^{2.8244}$ (Mason et al., 1983b). Females of mean length, about 60 cm (an age of about 5 years), thus produce about 120,000 eggs. With a mortality rate of 0.1 (McFarlane and Beamish 1983a) acting on post-settling fish for 4.5 years, a pair of spawners would represent 3.1 fish at settlement (July). The daily mortality rate required to reduce 120,000 eggs to 3.1 settlement juveniles in 6 months (February-July) would be 0.058.

Not enough is presently known of the distribution of eggs and yolk sac larvae of sablefish to estimate their mortality rate from field samples. Also, the neuston nets generally used to sample the larvae are avoided by larger larvae, especially during daytime, making it difficult to use these samples for mortality estimates.

Mortality of planktonic fish eggs and larvae is generally thought to be due to poor feeding, predation, and adverse drift, acting singly or in concert. The high food consumption rates and associated rapid growth may make food shortage a potentially significant source of mortality in sablefish larvae. Grover and Olla (1986) found emaciated small larvae in a field sample and concluded that a paucity of copepod nauplii was responsible for the condition which would have probably resulted in the death of the larvae. McFarlane and Beamish[11] speculated that strong year classes of sablefish off British Columbia are produced in years with above normal sea surface temperatures and increased onshore Ekman transport during the egg and larval period. Such conditions may favor high production of nauplii of *Neocalanus plumchrus* and *Neocalanus cristatus*, two of the most abundant copepods in the subarctic Pacific Ocean, which are probable food sources of young larval sablefish. Grover and Olla (In press) found that off Washington and Oregon in an El Niño year (1983) sablefish larvae had fed on more small southern copepods (*Paracalanus parvus*) than in a year without El Niño conditions. Water temperatures were higher and zooplankton volumes lower in the El Niño year. Thus, the factors contributing to sablefish larval food production may not be the same off British Columbia and Washington-Oregon.

No direct evidence on rates of predation on eggs or larvae of sablefish exists, although McFarlane and Beamish (1983b) reported the occurrence of juveniles in the guts of several species of fish and they are frequently found in salmon stomachs off southeastern Alaska in summer (Wing, 1985). Shenker and Olla (1986) observed a 14 mm SL sablefish in an aquarium being eaten by a 35 mm SL sablefish, and apparent avoidance behavior of a 27 mm SL specimen in the presence of a 35 mm SL fish. This would indicate that larval sablefish recognize the potential of predation by slightly larger fish. However, since sablefish larvae seem to occur singly and are relatively rare at sea, it is not probable that predators regularly key on them. The protective coloration (counter shaded: Dark on the dorsal surface, silvery on the ventral surface) is characteristic of other neustonic animals (e.g., hexagrammid larvae, Kendall and Vinter, 1984) and probably enhances the ability of larval sablefish to avoid predators.

Sablefish seem to spawn near the edge of the continental shelf in waters deeper than 300 m (McFarlane and Beamish, 1983a). Larvae occur up to at least 370 km from shore in the relatively fast moving surface waters. Young-of-the-year juveniles are found inshore in July (McFarlane and Beamish, 1983b). Thus, there is a possibility for onshore-offshore as well as alongshore transport of larvae, and an active inshore migration is indicated. The velocities of these physical transport mechanisms surely vary from year to year, and will influence the distribution and possible survival of young sablefish as they move to inshore nursery areas.

Early Life History Work in Relation to Management

In trying to manage the sablefish fish-

[10]Walline, P. D. 1981. Distribution of ichthyoplankton in the eastern Bering Sea during June and July 1979. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 81-3, 13 p.

[11]McFarlane, G. A., and R. J. Beamish. 1985. Production of strong year-classes of sablefish (*Anoplopoma fimbria*) off the west coast of Canada. Pac. Biol. Stn., Nanaimo, B.C. Draft manuscr. presented at 1985 Int. North Pac. Fish. Comm. symp.

ery using information from the adults alone, several difficulties arise (Sasaki, 1985), which early life history studies may help resolve. Assessment of population size is generally based on catch per unit of effort in standardized fishing gear (longlines, traps, or trawls), which can only give a measure of relative abundance and trends in abundance. Broad-scale surveys of pelagic eggs, when combined with data on population fecundity, avoid many of the problems associated with surveying adult abundance directly and can be used to estimate spawning biomass. Since sablefish spawn during a restricted time each year, this method of population assessment may be viable.

Year-class strength of sablefish is difficult to determine by sampling the fishery because of problems in determining the ages of older adults (Beamish et al., 1983). Year-class strength in fishes is thought to be determined mainly during the pelagic egg and larval stages. Thus with sablefish, epipelagic juvenile abundance may indicate year-class strength. These fish might be sampled efficiently when they are a few months old to give an indication of recruitment strength to the fishery several years later. Further work on the factors influencing survival of larval sablefish could enhance our understanding of the recruitment process and allow forecasts of year-class strength, which would permit a sounder long-term basis for management of the resource.

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Movements of Brown Shrimp, *Penaeus aztecus*, and Pink Shrimp, *P. duorarum*, Relative to the U.S.-Mexico Border in the Western Gulf of Mexico

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ABSTRACT—Seasonal movement patterns of marked brown shrimp, Penaeus aztecus, *and pink shrimp,* P. duorarum, *relative to the U.S.-Mexico border in the western Gulf of Mexico are described from recaptures of shrimp tagged during 1978-80. The intent was to determine the degree to which coastal shrimp movements would affect commercial catches after implementation of new fishing regulations off Texas and Mexico. Shrimp were collected by trawl, marked with polyethylene streamer tags, and released during March-November at sites between Galveston, Tex., and Tampico, Tamaulipas, Mexico. Movements were examined by vector analysis and by recaptures per unit commercial landings. Over 121,500 shrimp were marked during seven releases in estuaries, of which 1,827 (1.5 percent) were recaptured. Only 72 brown shrimp and 126 pink shrimp were recaptured offshore, but southerly movement patterns were indicated after five of those seven releases. Offshore releases of 71,485 brown shrimp and 19,185 pink shrimp resulted in 12.4 percent and 19.7 percent recapture proportions, respectively. Tagged brown shrimp moved up to 620 km from release sites and remained free up to 430 days. Tagged pink shrimp moved a maximum 428 km and were free up to 446 days. Recaptures were higher south of release sites after 20 of 30 releases of brown shrimp off Texas and Tamaulipas. In contrast, recaptures of pink shrimp were higher south of release sites after only 7 of 13 releases. The effectiveness of the Gulf of Mexico shrimp fishery management plan, enacted in 1981 to increase brown shrimp yield by seasonal prohibition of fishing, could be diminished by the tendency for brown shrimp to migrate south.*

Introduction

The major fishery for brown shrimp, *Penaeus aztecus*, occurs in the western Gulf of Mexico. Annual U.S. landings of brown shrimp off Texas averaged 13,800 metric tons (t) between 1970 and 1980, approximately 50 percent of the entire northern Gulf of Mexico catch (Klima et al., 1982). Annual catches off Tamaulipas and upper Veracruz, Mexico (lat. 21°-26°N) averaged 2,000 t in 1974-79 by Mexican vessels (Castro[1]) and 2,800 t in 1970-75 by U.S. vessels prior to the U.S. withdrawal from that fishery (NMFS, 1971-76). Pink shrimp, *Penaeus duorarum*, are caught by the brown shrimp fishery off Texas and Tamaulipas but are not separated by processors because they form 10 percent or less of the total catch (Klima et al., 1982).

Tagged brown shrimp and pink shrimp have been reported to move up to 435 km before recapture (Klima, 1963; Costello and Allen, 1966; Cody and Fuls, 1981; Castro et al.[2]). These longshore movements represent a potential loss of yield from the U.S. fishery due to management regulations in the United States and Mexico. By 1976 treaty, U.S. vessels were to withdraw from Mexico's shrimp fishery by January 1980 (GMFMC, 1981). Reported U.S. shrimp catches from the Tamaulipas coast declined from 534 t in 1976 to zero in 1979 (NMFS, 1977, 1978, and unpubl. data). During the same period, the U.S. Gulf of Mexico shrimp fishery management plan was being developed for implementation in 1981. The plan's objective was to increase yield of brown shrimp recruiting to the offshore fishery by delaying harvest of small shrimp until a larger, preferred size was reached (GMFMC, 1981). A 45- to 60-day prohibition of shrimping in the Texas territorial sea and the Federal Fishery Conservation Zone (FCZ) during peak emigration of brown shrimp from Texas estuaries was instituted in 1981. An effective management plan would depend in part upon detailed knowledge of shrimp movement patterns. The National Marine Fisheries Service, the Texas Parks and Wildlife Department, and the Instituto Nacional de la Pesca of Mexico tagged brown shrimp and pink shrimp along the Texas and Tamaulipas coasts during 1978-80 as a means of studying movement, growth, and mortality. To date, only the results of tagging off Texas have been published, and these articles did not relate recaptures to fishing pressure (Cody and Avent, 1980; Cody and Fuls, 1981; Castro et al.[2]). This paper documents shrimp movements on the continental shelf adjacent to Texas and Tamaulipas as influenced by fishing pressure, with particular reference to the Texas closed shrimp season.

Materials and Methods

We hypothesized that net longshore movements of shrimp populations, as measured by recapture of tagged shrimp

[1]Castro, Refugio G. Fundamentos y consideraciones para definir la temporada de veda en altamar y Laguna Madre en las costas de Tamaulipas en el noroeste del Golfo de Mexico. Unpubl. manuscr., 35 p. Departmento de Pesca, Instituto Nacional de la Pesca, Tampico, Tamaulipas, Mexico.

[2]Castro, Refugio G., Esteban Rosas, and Rolando Orta. Investigaciones conjuntas de camaron Mexico-E.U.A. en el Golfo de Mexico. Programo de marcado-recaptura de camaron en las costas de Tamaulipas, Mexico de 1978-1981. Unpubl. manuscr., 63 p. Instituto Nacional de la Pesca, Centro de Investigaciones Pesqueras, Tampico, Tamaulipas, Mexico.

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by commercial and recreational fishermen, were random with respect to both month and location of release. Tagged shrimp were released during May-November over 3 years (1978-80) although releases were not made in each month each year. Release locations were National Marine Fisheries Service statistical subareas 18-25 between Galveston, Tex., and Tampico, Tamaulipas (Fig. 1). Release sites within these locations were either localized inshore sites near estuary passes or dispersed offshore sites where adequate supplies of shrimp for tagging could be located. Offshore releases were made in many combinations of month, year, and location, but inshore releases were limited.

All shrimp were collected by trawl and marked with colored, numbered polyethylene streamer tags as described by Marullo et al. (1976). Shrimp were released by dipnet or chute (10 cm diameter hose) in shallow inshore waters and by expendable release canister offshore. Each canister was weighted, loaded with 50-75 shrimp, and sealed with a salt block that dissolved and freed the shrimp after 10-15 minutes on the sea floor (Emiliani, 1971). Periodic lottery rewards of up to $500 were offered as an incentive to fishermen who caught tagged shrimp and provided information on locations and dates of recaptures (Cody and Fuls, 1981).

Tagged shrimp were identified before release with the exception of September 1978 releases off Tamaulipas. Cody and Fuls (1981) reported that the proportion of pink shrimp among all recaptures after release off Texas in October 1978 was similar to the proportion of pink shrimp among all shrimp released at that time (4.6 vs. 5.2 percent). Thus, numbers stated for brown shrimp and pink shrimp released in September 1978 off Tamaulipas were estimated from the total number released multiplied by the proportion of each species among recaptures.

Evaluation of directional movement employed two methods: Vector analysis of recaptures (Cody and Avent, 1980; Cody and Fuls, 1981) and recaptures per 10^3 t of commercial landings. Vector analysis assumed uniform catch in time and space and straight line movement

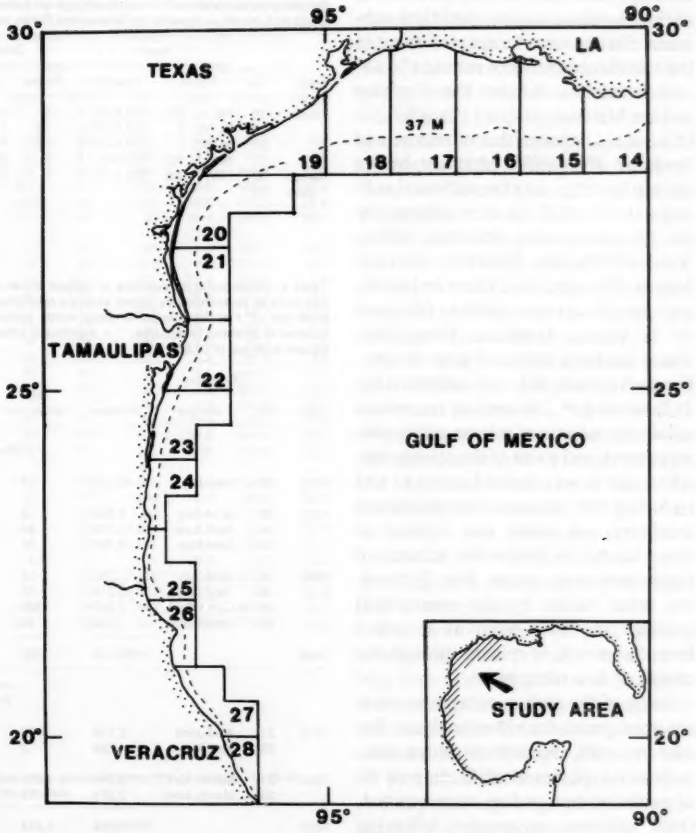

Figure 1.—Statistical subareas of the Gulf of Mexico in which marked shrimp were released (18-25) and later recaptured (14-28).

from release site to recapture site. To determine longshore movements of shrimp in each statistical subarea, the 360° compass configuration was divided into octants with midpoints corresponding to the compass points N, NE, E, SE, S, SW, W, and NW. The approximate orientation of the 37 m isobath in each statistical subarea (NOS Chart 411) was matched to an opposing pair of these octants to determine longshore (parallel to coastline) and onshore-offshore (perpendicular to coastline) directions as well as compass heading ranges for these directions. Three octants were assigned to each longshore direction while one octant each was assigned to onshore and offshore (Table 1). Longshore movement toward the Mississippi River was termed "north" while longshore movement toward Veracruz, Mexico, was termed "south". The vector heading (in degrees) and the distance traveled for each recaptured shrimp were calculated from tag return data, and each recapture was then assigned to one of the four coastwise categories. It was hypothesized that after each release dispersal was random, and significant departures from the expected 1:1 north-south ratio in the numbers of recaptures was tested by chi-square analysis ($P<0.05$). Onshore and offshore recaptures were excluded because they did not address longshore movement.

Recaptures per 10^3 t of commercial

landings (R/L) corrects for variation in shrimp landings among statistical subareas. Shrimp were recaptured either in the statistical subarea of release ("within"), in subareas between that of release and the Mississippi River ("north"), or in subareas between that of release and Veracruz ("south"). Monthly brown shrimp landings data for statistical subareas 14-21 and 22-26 were collected by the Economics and Statistics Office, National Marine Fisheries Service, Miami, Fla., and the Centro de Investigaciones Pesqueras, Instituto Nacional de la Pesca, Tampico, Tamaulipas. These landings included pink shrimp. For each release, R/L was calculated by: 1) Tabulating the number of recaptures within the subarea of release and in subareas north and south of the release site, where north was defined as up to and including the subarea of northernmost recapture and south was defined as down to and including the subarea of southernmost recapture, then 2) dividing those values by the commercial landings in those subareas recorded from the month of release through the month of last recapture.

Some of the shrimp recaptures were not appropriate for either analysis. Recaptures with incomplete return data, such as no species identification or inaccurate location or date, were omitted. Only offshore recaptures following inshore releases were analyzed. Recaptures within 9 km of the offshore release sites were excluded from vector analysis because a minor error in recapture location could have led to a major error in apparent movement direction over such a short distance.

Table 1.—Compass points and heading ranges (degrees) corresponding to shrimp movements relative to shore by statistical subareas of release. Headings are based on the approximate orientation of the 37 m isobath on NOS Chart 411. North = toward the Mississippi River; south = toward Veracruz, Mexico; SS = statistical subarea.

		North		Offshore		South		Onshore	
Area	SS	Points	Headings	Points	Headings	Points	Headings	Points	Headings
Texas	18	NE, E, SE	022.5-157.4	S	157.5-202.4	SW, W, NW	202.5-337.4	N	337.5-022.4
	19	N, NE, E	337.5-112.4	SE	112.5-157.4	S, SW, W	157.5-292.4	NW	292.5-337.4
	20	N, NE, E	337.5-112.4	SE	112.5-157.4	S, SW, W	157.5-292.4	NW	292.5-337.4
	21	NW, N, NE	292.5-067.4	E	067.5-112.4	SE, S, SW	112.5-247.4	W	247.5-292.4
Tamaulipas	22-25	NW, N, NE	292.5-067.4	E	067.5-112.4	SE, S, SW	112.5-247.4	W	247.5-292.4

Table 2.—Directional movements of tagged brown shrimp and pink shrimp released in Texas and Tamaulipas estuaries as determined by vector analysis of offshore recaptures north and south of release sites and by recaptures per 10^3 t of commercial landings north, within, and south of the statistical subarea (SS) of release. N = number of offshore recaptures, * = significant difference in expected 1:1 north-south ratio as indicated by chi-square analysis ($P<0.05$).

		Releases		Total recaptures	Vector analysis[1]			Recaptures per 10^3 t			
Year	SS	Months	Number		N	North	South	N	North	Within	South
				Brown shrimp							
1978	20	May-July	42,180	7	0			0			
1979	20	June-July	9,598	0	0			0			
	21	April-June	15,776	84	18	2	4	18	0.0	11.6	42.2
	23	April-May	10,083	31	2	1	1	2	0.0	1.9	2.8
1980	18	June-July	11,350	1	0			0			
	19	May, July	10,218	10	0			0			
	21	March-April	2,912	229	11	4	7	11	0.0	1.6	48.0
	23	March-June	4,362	31	5	1	4	5	8.4	9.0	0.0
Total			106,479	393	36			36			
				Pink shrimp							
1979	21	April-June	2,778	123	35	12	6	35	0.5	11.1	27.4
	23	April-May	384	2	0			0			
1980	21	March-April	9,548	1,296	82	23	59*	82	0.5	13.8	21.9
	23	March-June	2,374	13	2	1	1	2	18.9	4.8	0.0
Total			15,084	1,434	119			119			

[1]N – (North + South) = number of onshore/offshore recaptures.

Results

The available evidence indicates that net population movement of tagged brown shrimp along the Texas-Tamaulipas coast was southward after 1978-80 releases. Three of four inshore releases and 20 of 30 offshore brown shrimp releases resulted in higher R/L values south of release sites. Southerly movement was not consistent, however, as the remaining 10 releases had higher R/L values to the north. Pink shrimp had a more variable movement pattern since two of three inshore releases and only 7 of 13 primary offshore releases resulted in higher R/L values to the south.

Over 121,500 brown shrimp and pink shrimp were marked and released in estuarine waters but, with three exceptions, recaptures after inshore releases were <1 percent of those released (Table 2). Poor recoveries were probably due to stress by handling, high water temperature, predation, or attacks of tagged shrimp by untagged shrimp (Cody and Avent, 1980; Howe and Hoyt, 1982). Twelve inshore releases were conducted but only one was followed by directional movement as indicated by vector analysis. Pink shrimp recaptured after release during March-April 1980 in statistical subarea 21 demonstrated significant southward movement. R/L values for the seven inshore releases with subsequent offshore recaptures, however, indicated southward movement after three brown shrimp releases and two pink shrimp releases. All transborder recaptures (7 brown shrimp, 31 pink shrimp) were made from shrimp released in the Laguna Madre of Texas, most likely because the Brazos-Santiago Pass from the Laguna Madre of Texas is only 15 km from the border while Boca de Catan, near the tagging site in the Laguna Madre of Tamaulipas, is 175 km from the border.

Vector analysis of brown shrimp recaptures (Table 3) generally indicated significant southward migration. Southerly movements occurred spring through fall while northerly movements

Table 3.—Directional movements of tagged brown shrimp released off Texas and Tamaulipas as determined by vector analysis of recaptures north and south of release sites and by recaptures per 10^3 t of commercial landings north, within, and south of the statistical subarea (SS) of release. N = number of recaptures appropriate for analysis, * = significant difference in expected 1:1 north-south ratio as indicated by chi-square analysis ($P<0.05$).

Releases				Total recaptures	Vector analysis[1]			Recaptures per 10^3 t			
Year	SS	Months	Number		N	North	South	N	North	Within	South
1978	20	August	2,832	193	73	45*	24	171	4.0	63.6	2.4
		October	1,430	153	101	30	64*	127	1.5	41.7	4.6
	22	September	2,011	336	264	42	222*	264	0.3	242.7	65.8
	23	September	5,859	1,416	1,205	297	889*	1,250	10.9	388.2	421.8
	24	September	539	62	46	20	26	61	10.6	171.1	27.6
	25	September	503	64	59	21	36	62	10.4	265.8	58.6
1979	18	September	771	120	66	5	57*	86	0.5	105.0	18.5
	19	September	1,760	158	89	19	65*	121	3.3	114.1	6.7
		October	8,270	1,039	796	53	607*	811	13.4	155.3	4.4
		November	2,569	109	80	44	30	95	25.9	74.4	3.4
	20	May	978	139	95	21	47*	115	0.0	18.5	35.0
		September	349	37	30	18	11	33	6.7	16.3	8.7
		October	1,106	225	156	28	104*	196	3.0	50.3	10.6
	21	May	1,620	444	141	59	78	191	3.7	51.4	3.9
	22	May	519	132	92	25	46*	98	3.2	445.5	14.2
		June	1,509	183	112	8	90*	167	0.5	573.0	70.0
		September	168	12	10	1	9*	10	0.0	110.6	23.1
	23	May	549	121	86	34	52	86	175.8	75.1	17.9
		June	1,224	193	110	36	66*	176	239.9	243.3	69.1
	24	June	2,618	459	357	235*	118	423	34.2	768.3	16.1
1980	19	June	11,677	882	437	177	241*	653	16.4	156.5	7.4
		July	10,545	873	336	34	277*	598	5.0	98.0	28.3
	20	June	2,013	67	47	12	20	52	2.8	12.8	2.4
		July	4,362	229	163	7	150*	220	0.3	30.4	40.4
	21	May	423	113	83	28	46*	101	2.4	34.3	15.1
		June	298	15	14	6	6	14	0.7	2.6	8.5
	22	May	883	106	100	44	40	105	4.5	214.4	11.9
	23	May	974	129	93	37	53	121	152.5	73.5	25.0
	24	May	1,062	152	71	35	28	143	25.6	328.6	33.4
	25	May	2,064	666	536	367*	169	641	105.2	779.6	0.0
Total			71,485	8,827	5,848			7,191			

[1]N – (North + South) = number of onshore/offshore recaptures.

Table 4.—Percentage of brown shrimp recaptures by days free, state, and months of release, 1978-80. N = total number recaptured.

State	Release months	N	Days free						
			1-10	11-20	21-30	31-40	41-60	61-100	101+
Texas	May	696	36	18	12	8	16	5	6
	June-August	2,259	44	17	18	9	7	3	1
	September-November	1,841	28	22	18	8	13	7	4
	Total	4,796	36	19	17	8	11	5	3
Tamaulipas	May	1,306	16	32	19	14	10	6	4
	June-August	835	27	22	26	9	9	7	1
	September-November	1,890	15	29	25	13	9	7	4
	Total	4,031	17	28	23	12	9	7	3

were noted in spring and summer. R/L values also indicated that brown shrimp moved south more frequently than north. Eleven of 16 Texas releases and 9 of 14 Tamaulipas releases resulted in higher R/L values in statistical subareas south of the release sites. Five Texas releases and five Tamaulipas releases resulted in higher R/L values north of the release sites. Both southerly and northerly movements of brown shrimp occurred spring through fall, as indicated by R/L values. Of the 19 vector analyses indicating significant movement of brown shrimp, 16 of the corresponding R/L values agreed on direction of movement.

An examination of tag returns over time (Table 4) indicated that about 70 percent of all tagged brown shrimp were returned within 30 days of Texas and Tamaulipas release. Recaptures after 1-10 days free were higher in Texas than in Tamaulipas (36 vs. 17 percent of the respective total numbers returned), but the reverse was true after 11-30 days free (36 vs. 52 percent, respectively). On a seasonal basis, tag returns occurred more rapidly after June-August releases (the main shrimping season) than after spring or fall releases off each state.

Maximum long distance movements by marked brown shrimp included 620 km within U.S. waters, 596 km from Texas to Tamaulipas, 528 km from Tamaulipas to Texas, and 526 km within Mexican waters. Maximum days at large were 390 days within U.S. waters, 430 days for a Texas release-Tamaulipas recapture, 400 days for the reverse, and 353 days within Mexican waters.

Vector analysis of pink shrimp recaptures (Table 5) indicated no overall movement pattern. R/L values for pink shrimp recaptures indicated southward movement after seven primary releases and northward movement after the remaining six releases. Of the seven vector analyses indicating significant directional movement, six of the corresponding R/L values agreed on direction of movement.

The time course of pink shrimp recaptures after primary releases in May-June (Table 6) differed between the two release states. Only 40 percent of the returns after Texas releases had been recorded within 30 days, compared with 67 percent of the Tamaulipas releases. A comparatively large proportion (34 percent) of the recaptures after Texas releases came after 41-60 days free. Some 50 percent of the recaptures after incidental releases were made within 30 days. The maximum distances traveled by marked pink shrimp were 428 km from Texas to Tamaulipas, 380 km from Tamaulipas to Texas, 400 km within U.S. waters, and 398 km within Mexican waters. Maximum days at large for these same spatial areas were 391, 446, 436, and 344 days, respectively.

Transborder movements of tagged brown shrimp and pink shrimp were recorded each year (Table 7). Transborder recaptures primarily followed releases in subareas 21 and 22 adjoining the U.S.-Mexico border. However, one pink shrimp traveled from subarea 20 and five brown shrimp traveled from subarea 19 into Tamaulipas waters, while two pink shrimp from subarea 23 and one brown shrimp from subarea 24 were recaptured in Texas waters.

Discussion

R/L values are the preferred of our two indicators of shrimp movement because R/L depends on marked shrimp that move completely out of the subarea of release and thus are exhibiting long-range, directed movement. R/L values also compensate for nonuniform commercial shrimp landings among statistical subareas. Vector analysis is useful as a secondary indicator of shrimp movement because it reflects primarily short-range movements (usually within the subarea of release), but it assumes a uniform pattern in landings which rarely occurs. Our definition of longshore movement for the vector analyses is also liberal in that 75 percent of all recaptures are assumed to be showing longshore movement. Perhaps a better indicator of shrimp movement would be recaptures per unit effort, but these data were not available for the complete study period on both sides of the border.

Brown shrimp and pink shrimp migrations may be related to food, substrate, or currents. The offshore diets of these species have not been investigated, but if infaunal organisms are a primary food as they are inshore (Williams, 1955; Eldred et al., 1961; Sastrakusumah, 1971), then brown shrimp and pink shrimp might be attracted to the areas of densest infaunal assemblages (Williams, 1958). Along the south Texas coast, these areas are found on the relict Rio Grande Delta (Hill et al., 1982) in statistical subarea 21. This is also an area of unique sedimentary characteristics along the Texas coast (Shideler, 1978), but the offshore sediment preferences of penaeid shrimps have not been examined directly (Grady, 1971). Experiments with juvenile shrimp indicate that pink shrimp may seek coarse substrates (Williams, 1958) or be competitively displaced from fine-grained substrates by the more numerous brown shrimp (Rulifson, 1981), both factors that may influence shrimp recapture patterns. Statistical subarea 19 has traditionally yielded the largest catches of brown shrimp, most likely because it contains 26-85 percent more bottom area in the most productive depth stratum (20-46 m) than is contained in statistical subareas 18, 20, or 21 (Patella, 1975; Klima et al., 1982). Infaunal and sedimentary patterns on the Tamaulipas shelf are not known, although highest shrimp catches in statistical subareas 22-24 are also made in 20-46 m waters (Griffin and Beattie, 1977).

Prevailing bottom currents may also influence the observed patterns in recaptures of tagged shrimp. Upcurrent migration have been reported for king prawn moving to spawning areas on the

Table 5.—Directional movements of tagged pink shrimp released off Texas and Tamaulipas as determined by vector analysis of recaptures north and south of release sites and by recaptures per 10^3 t of commercial landings north, within, and south of the statistical subarea (SS) of release. N = number of recaptures appropriate for analysis, * = significant difference in expected 1:1 north-south ratio as indicated by chi-square analysis ($P<0.05$).

Releases					Vector analysis[1]			Recaptures per 10^3 t			
Year	SS	Months	Number	Total recaptures	N	North	South	N	North	Within	South
1978	20	October	68	7	5	2	3	6	0.9	3.9	1.6
	22	September	23	4	3	2	1	3	1.2	5.6	1.6
	23	September	24	5	5	0	5	5	0.0	0.0	77.4
	24	September	65	9	6	2	4	8	3.6	12.1	5.7
	25	September	77	12	9	2	7	10	6.6	45.2	0.0
1979	18	September	4	1	1	1	0	1	0.0	6.0	0.0
	19	September	86	3	2	1	1	2	6.0	0.0	1.8
	20	May	361	49	31	7	20*	39	0.0	6.3	9.4
		September	34	1	1	0	1	0	0.0	2.1	0.0
		October	17	1	0	0	0	0	0.0	0.0	0.0
	21	May	8,463	1,793	1,068	454	585*	1,688	16.4	359.1	26.1
	22	May	846	195	164	54	75	182	2.8	382.7	10.8
		June	68	6	2	0	2	5	0.0	23.3	4.3
		September	26	0	0	0	0	0	0.0	0.0	0.0
	23	May	819	120	111	47	64	111	169.6	64.2	6.6
		June	367	32	16	1	13*	17	0.0	13.6	22.9
	24	June	421	77	68	34	34	73	19.5	133.0	16.1
1980	20	June	235	17	12	6	4	14	5.5	9.9	2.1
		July	15	4	4	1	3	4	0.3	0.0	1.0
	21	May	2,885	812	549	399*	138	778	13.7	207.2	11.8
		June	386	93	68	39*	17	87	7.2	38.7	0.0
	22	May	1,035	102	95	53	36	99	6.0	178.0	6.4
	23	May	1,203	202	125	53	68	189	14.3	139.6	17.0
	24	May	1,134	166	70	38*	21	163	17.7	317.2	22.3
	25	May	523	59	47	36*	11	58	16.4	54.0	4.7
Total			19,185	3,770	2,462			3,538			

[1]N – (North + South) = number of onshore/offshore recaptures.

Table 6.—Percentage of pink shrimp recaptures by days free, state, and months of release, 1978-80. N = total number recaptured.

State	Release months	N	Days free						
			1-10	11-20	21-30	31-40	41-60	61-100	101+
Texas	May-June	2,768	31	4	5	10	34	11	4
	September-October	13	23	15	8	8	31	15	0
	Total	2,781	31	4	5	10	34	11	4
Tamaulipas	May-June	959	27	23	17	9	14	6	4
	September-October	30	20	23	7	7	10	17	17
	Total	989	27	23	17	9	14	6	4

Table 7.—Total number of recaptures and number and percentage of transborder recaptures (in parentheses) from all brown shrimp and pink shrimp releases by statistical subareas of release.

Release subarea	Brown shrimp recaptures		Pink shrimp recaptures	
	Total	Transborder	Total	Transborder
18	120	0 (0.0)	1	0 (0.0)
19	3,060	5 (0.2)	3	0 (0.0
20	1,043	10 (1.0)	79	1 (1.3)
21	572	12 (2.1)	2,698	82 (3.0)
22	769	46 (6.0)	307	72 (23.5)
23	1,859	2 (0.1)	359	2 (0.6)
24	673	1 (0.1)	252	0 (0.0)
25	730	0 (0.0)	72	0 (0.0)

Australian continental shelf (Ruello, 1975). Bottom currents in statistical subareas 18-21 are generally southerly in spring and fall and variable to northerly in summer (Armstrong, 1980; Smith, 1980; Lewis, 1982; McGrail, 1983). The only published measurements off Tamaulipas indicate southerly bottom currents in summer in waters >100 m deep (Vazquez de la Cerda, 1975). Thus, adult shrimp marked in spring and fall may drift south with the currents, while shrimp tagged in summer would have to swim actively against the northerly currents, at least in Texas waters, to have a southerly dispersal.

The results of these shrimp mark-recapture experiments bear upon the present U.S. shrimp fishery management plan and any future U.S.-Mexico agreements to exploit the fisheries. Peak emigration of brown shrimp from the Laguna Madre of Tamaulipas (statistical subarea 23) occurs in mid-to-late May with a subsequent acceleration in offshore catches in June (Castro[1]). Peaks in brown shrimp emigration from Texas estuaries typically occur in late May-early June in statistical subareas 20 and 21 and later in statistical subareas 18 and 19 (Benefield and Baker, 1980; Matthews, 1982). The shrimp fishery management plan mandates a 45- to 60-day closed season beginning about 1 June each year. During the ensuing 3 months, the present study indicates that the degree of success in achieving the shrimp management plan's objective (increasing yield) may be influenced by the tendency of brown shrimp and pink shrimp to move south, particularly in the border area. All four inshore releases of tagged brown shrimp and pink shrimp between March and June in statistical subarea 21 resulted in greater southward movement than northward movement. Three offshore releases of brown shrimp and pink shrimp were conducted in each of subareas 21 and 22 during May through August. All brown shrimp recapture patterns described stronger southerly movement than northerly movement, while four of six pink shrimp releases had similar results. The Texas Closure delivered positive benefits to the fishery in its first four years (1981-84). Annual Gulf-wide yields attributed to the closure of the FCZ off Texas have ranged between 181 t in 1983 (1 percent increase in catch) and 1,905 t in 1981 (4 percent increase), with annual value increases ranging between $6.0 million (3 percent) in 1982 and $9.7 million (4 percent) in 1981 (Klima and Nichols[3]). Yields might be improved if the shrimp management plan considered the migratory behavior of brown shrimp and pink shrimp.

Acknowledgments

We thank Terry Cody of the Texas Parks and Wildlife Department and Refugio Castro of the Instituto Nacional de la Pesca for their assistance and numerous reviewers for their constructive comments.

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The Cooperative MEXUS-Gulf Research Program: Summary Reports for 1977-85

A Special Section of the
Marine Fisheries Review

Sponsored by the
Southeast Fisheries Center,
National Marine Fisheries Service,
NOAA, U.S. Department of Commerce,
75 Rickenbacker Causeway,
Virginia Key, Miami, FL 33149

Editors: William J. Richards and Rolf Juhl

Preamble

This special section of the *Marine Fisheries Review* includes six summary reports covering activities from 1977 through mid-1985 directly related to the MEXUS-Gulf Program.

MEXUS-Gulf is a fisheries agreement between the Instituto Nacional de Pesca of the Mexican Ministry of Fisheries and the Southeast Fisheries Center of the National Marine Fisheries Service. The focus is on cooperative fishery research and technology on projects of mutual interest in the Gulf of Mexico and Caribbean. Working groups are formed to conduct research and report on specific fishery projects. A co-leader from each institution coordinates the work. Annual meetings are held, where results from the previous year are presented and discussed and where plans for next year's research are made and approved.

The Mexico delegation consists of the Director of the Instituto Nacional de Pesca, as Co-Director of MEXUS-Gulf, representatives of the Secretaria de Pesca, co-leaders of the working groups, and representatives of the Instituto Nacional de Pesca. The U.S. delegation consists of the Director of the NMFS Southeast Fisheries Center, as Co-Director of MEXUS-Gulf, representatives from the Washington office of the National Marine Fisheries Service, co-leaders of the working groups, and invited fishery interest representatives from the Gulf Coast states.

MEXUS-Gulf had its genesis in the plan to phase out U.S. shrimp fishing in Mexican waters, which terminated in December 1979, under the November 1976 Bilateral Fisheries Agreement between the United States and Mexico. Incorporated in that agreement was a statement requiring that a bilateral scientific committee be established to maintain active fishery research in the Gulf of Mexico and to keep lines of communication open. At the request of either government, a bilateral panel could be established to deal with areas of fishery research of mutual interest.

In 1977, the Directors of the Instituto Nacional de Pesca and the Southeast Fisheries Center conceived the plan of MEXUS-Gulf, to be sponsored by their two organizations. The first MEXUS-Gulf meeting was held in Campeche, Mexico, and the second was held in Key Biscayne, Fla., where plans were made to form a series of working groups that would address specific problems in fisheries. The latest meeting was held in Houston, Tex., in October 1985.

The initial working groups were: Ichthyoplankton, shrimp, demersal fish, coastal pelagic fish, pollution, sea turtles, and hydroacoustics. Since then, some groups have been dropped and others added. The current groups are: Shrimp, demersal fish, coastal pelagic fish, ichthyoplankton, remote sensing and harvesting technology, sea turtles, recreational fisheries, and aquaculture, the latest addition. The reports published here are from the first six of these working groups.

MEXUS-Gulf Shrimp Research, 1978-84

EDWARD F. KLIMA, REFUGIO GMO. CASTRO MELENDEZ, NEAL BAXTER,
FRANK J. PATELLA, TERRY J. CODY, and LORETTA F. SULLIVAN

Introduction

Mexico and the United States share shrimp and other marine resources in the Gulf of Mexico. As a result, in 1977 a cooperative research agreement was established between the Federal fisheries research organizations of the two countries—the Departmento de Pesca's Instituto Nacional de Pesca (INP) and the National Marine Fisheries Service's (NMFS) Southeast Fisheries Center—to develop joint marine research programs. At the first MEXUS-Gulf meeting in Campeche, Mex. (1977) a shrimp working group developed cooperative research plans to determine migration, growth and mortality rates of brown and pink shrimp, and to define the fishing characteristics of the U.S. and Mexican shrimp fleets. This report summarizes the first 7 years' results from this cooperative research and suggests the direction of the program for the next 2 years (1985-86).

Background and the Fishery

Total shrimp production in the Gulf of Mexico in 1977 was about 148,000 metric tons (t), heads on, whereas in 1978 it decreased slightly to 139,000 t. The fishery originally consisted of both U.S. and Mexican vessels fishing Mexican waters and primarily U.S. boats fishing U.S. waters. Since 1979, however, U.S. vessels have not been allowed in Mexican waters.

The distribution and relative abundance of white shrimp, *Penaeus setiferus*; brown shrimp, *P. aztecus*; and pink shrimp, *P. duorarum*, have been described by Osborn et al. (1969) and are depicted in Figures 1, 2, and 3, respectively. The brown shrimp population is distributed throughout the northern and western Gulf of Mexico, with the center of abundance off Texas. White and pink shrimp are also distributed throughout the northern half of the Gulf, with the center of white shrimp abundance off Louisiana and that of pink shrimp off southern Florida, with highest concentrations around the Dry Tortugas and Campeche areas. There appear to be two separate stocks of pink shrimp, one on the Campeche Bank off Mexico and the other on the Tortugas and Sanibel grounds off south Florida. White shrimp are believed to have a continuous distribution throughout the northern half of the Gulf and south into Mexico.

Lindner and Anderson (1956) described the results of tagging studies which clearly indicated white shrimp moved across the U.S.-Mexico border. The species composition in the Tampico-Texas fishery is believed to be predominantly brown shrimp. Exact percentages are not available because all shrimp, regardless of species, landed are are recorded as brown shrimp by both the United States and Mexico. Further,

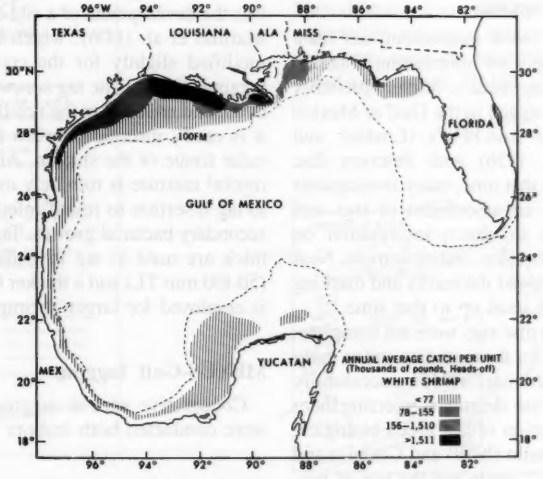

Figure 1.—Distribution of catch per unit (thousands of pounds) of white shrimp in the Gulf of Mexico.

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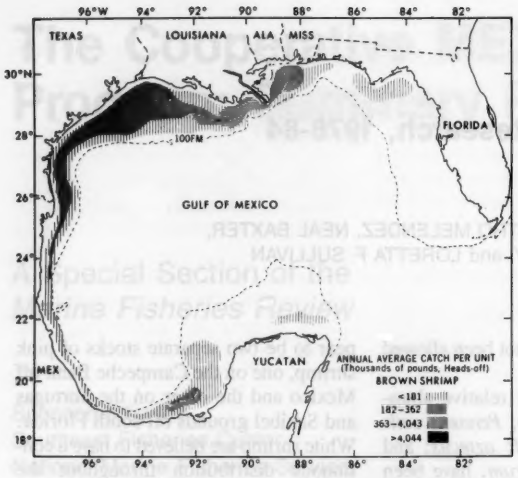

Figure 2.—Distribution of catch per unit (thousands of pounds) of brown shrimp in the Gulf of Mexico.

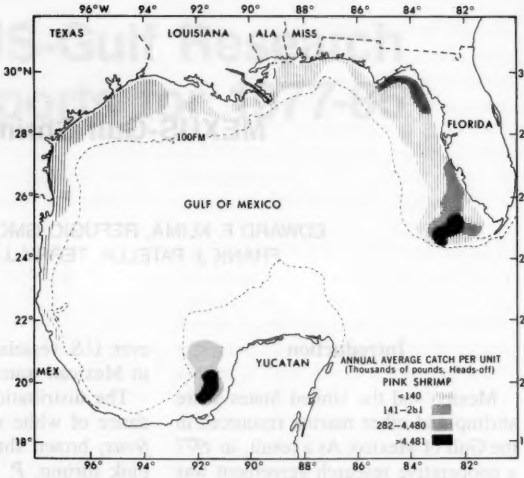

Figure 3.—Distribution of catch per unit (thousands of pounds) of pink shrimp in the Gulf of Mexico.

information concerning transboundary movement of the brown and pink shrimp stocks is also unknown and formulated the basis for a major study by the MEXUS-Gulf shrimp working group.

Methods

Shrimp Tagging

Shrimp stock assessment has been based largely on information obtained from tagging studies. Shrimp probably were first tagged in the Gulf of Mexico during the mid-1930's (Lindner and Anderson, 1956) with Petersen disc tags. Since that time, many investigators have used an assortment of tags and techniques to obtain information on growth, mortality, and movement. Neal (1969) reviewed the marks and marking procedures used up to that time.

Petersen disc tags were not completely suitable for these studies and as early as 1955, Menzel (1955) successfully marked white shrimp by injecting them with a solution of fast green biological stain. Costello (1959) and Costello and Allen (1962) perfected the use of biological stains for penaeid shrimp marking and evaluated the effectiveness of these stains and injection techniques. The stain injection technique was later used in the Gulf area by Klima (1964, 1974), Allen and Costello (1966), and Knight and Berry (1967), but was severely limited because only groups of shrimp and not individuals could be identified.

The next stage in the evolution of tags was the development of a ribbon tag by Marullo et al. (1976), which has been modified slightly for the cooperative tagging studies. The tag is now tapered at the end attached to the needle so that it is easily inserted between the muscular tissue of the shrimp. An Aureomycin[1] mixture is routinely used prior to tag insertion to retard infection and secondary bacterial growth. Tags 4 mils thick are used to tag juvenile shrimp (50-100 mm TL) and a thicker 6-mil tag is employed for larger shrimp.

MEXUS-Gulf Tagging

Cooperative shrimp tagging efforts were conducted both inshore and offshore U.S. and Mexico waters from 1978 to 1981. Tagging procedures and methods have been described by Neal (1969), Emiliani (1971), and Baxter and Hollaway (1981). In the offshore studies, shrimp were caught by the FRS *Oregon II* or the *Marcep II*, with tows limited to 15 minutes to lessen stress on the shrimp. The animals were maintained in 500 L flow-through tanks fitted with aluminum baffles to reduce the effects of vessel roll. All shrimp were tagged with serially numbered ribbon tags.

Tagged animals were placed in an expendable canister (Emiliani, 1971) and released overboard while the vessel was underway. Within about 10 minutes after dropping to the bottom, the canister opened, allowing shrimp to escape. This presumably reduced mortality by predation at the release site and was a standard technique for this study.

Shrimp Recovery and Awards

To increase the return of captured shrimp, a fishing contest was established in 1977. Fishing contests were held in both the United States and Mexico every 45 days during major recovery periods, with winners for each contest awarded first ($500), second ($200), third

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

($100), and fourth ($50) prizes (Fig. 4). This awards system was used until the September 1979 contest, when the number of winners in each contest was increased. Awards of $500 (one), $100 (one) and $50 (six) were given in the September 1979 and all subsequent drawings. Winning numbers were preselected by computer at the time of release by a priority system. If the first priority tag selected was not recovered, the second priority tag was selected and so on until four winners were identified. Tagged shrimp were returned to port agents located in the major ports. These agents collected catch and fishery effort statistics, handled the recovery of tagged shrimp, and had a major responsibility for obtaining and verifying pertinent information on area and date of recapture.

Data Analysis

Growth in length of brown and pink shrimp during the April-August period was estimated from 1978-81 mark-capture data. These data included tail length (the distance from the first body segment to the posterior end of the telson) when released and recaptured, the dates of release and recapture, and the sex of each individual. Data entries with the same release and recapture data do not reflect growth and therefore were not included.

Parrack's (1979) methods were used to estimate the growth functions which he expressed in terms of the change in the age rather than absolute age. He noted that recaptured individuals were of some unknown age on the date marked and on the date recaptured so that the change in age is equivalent to the time at large. Parrack rearranged the von Bertalanffy equation from:

$$S_a = S_\infty (1 - be^{-ka}) \quad \text{to}$$

$$S_r = S_\infty - (S_\infty - S_m)e^{-K(\Delta a)}$$

where:

S_a = size at age a,
S_r = size at recapture,
S = asymptotic size,
b = an equation constant related to the size at birth, and
S_m = size when marked.

We also used Parrack's technique to estimate the equation parameter S by utilizing the Marquardt algorithm to minimize the residual sum of squares.

We calculated the growth function for sexes combined to provide a description of population growth rather than estimating growth for each sex. The ratio of males to females throughout the recovery period did not appear to change from 1:1; therefore, we concluded that the growth function was adequate to describe growth of sexes combined.

Commercial Catch Data

Commercial catch statistics were collected by the INP in Mexico and the NMFS Southeast Fisheries Center in the United States. The catch statistics were reported by statistical subareas (Fig. 5) and were used to determine general population trends. NMFS commercial

PARTICIPE EN TORNEO DE PESCA DE CAMARON
PREMIOS EN EFECTIVO
DE $50 A $500 DOLARES
CAMARONES CON MARCAS INSERTADAS
Marca con listón de plástico azul
Marca con listón de plástico anaranjado
Las personas que entreguen los camarones con marcas participarán en sorteos bimestrales ,a través de cada número impreso en los listones; como en una lotería. En cada sorteo se darán cuatro premios y los números no premiados tendrán oportunidad de participar de nuevo en otros sorteos. Este sistema será permanente hasta 1979.
PREMIOS EN DOLARES $500 PRIMERO $200 SEGUNDO $100 TERCERO $50 CUARTO
Los camarones con marcas, indicando fecha y lugar de captura, deberán ser entregados al centro de investigación pesquera u oficina de pesca más próximos.
OFICINA
DIRECCION
TELEFONO
SI USTED ENCONTRO UN CAMARON MARCADO O SABE QUE ALGUIEN LO HIZO, AVISE A LA OFICINA DE PESCA
ESTE ES UN ESFUERZO CONJUNTO DEL DEPARTAMENTO DE PESCA DE MEXICO Y EL NATIONAL MARINE FISHERIES SERVICE, E. U. A. PARA EL ESTUDIO DE LOS HABITOS MIGRATORIOS, ABUNDANCIA, CRECIMIENTO Y MORTALIDAD DE LOS CAMARONES.

Figure 4.—Poster advertising shrimp incentive award system.

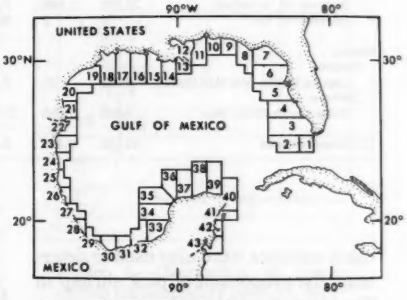

Figure 5.—NMFS grid system used to record shrimp statistics.

Table 1.—Release (Rel.) and recapture (Rec.) summary for 1978 shrimp tagging studies (number of species released not recorded by species).

Release area time	Brown			Pink			White			Spp. unknown			Totals		
	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%
Texas															
Inshore															
Port Mansfield, May	0	2	0	0	0	0	0	0	0	3,873	1	0	3,873	3	0.98
Rockport, June/July	0	4	0	0	0	0	0	0	0	38,307	0	0	38,307	4	0.01
Offshore															
Subarea 20, Aug./Sept.	0	327	0	0	7	0	0	1	0	4,330	14	0	4,330	349	8.06
Mexico															
Offshore															
Subareas 22-24, Sept./Oct.	0	1,874	0	0	30	0	0	0	0	9,024	4	0	9,024	1,908	21.14
Combined releases	0	2,207	0	0	37	0	0	1	0	55,534	19	0	55,534	2,264	4.08

Table 2.—Release and recapture summary for 1979 shrimp tagging studies (number of species released not recorded in all species).

Release area time	Brown			Pink			White			Spp. unknown			Totals		
	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%
Texas															
Inshore															
Port Isabel, April-June	15,768	84	0.53	2,786	123	4.41	0	0	0	24	17	0.09	18,578	224	1.21
Rockport, June/July	9,598	0	0	0	0	0	0	0	0	8	0	0	9,606	0	0
Port O'Connor, Sept./Oct.	0	0	0	0	0	0	0	179	0	10,103	5	0	10,103	186	1.84
San Luis Pass, Sept.-Nov.	0	0	0	0	0	0	0	46	0	10,120	7	0	10,120	53	0.52
Offshore															
Subareas 20-21, May/Sept./Oct.	5,791	792	13.68	8,879	1,845	20.78	1,841	241	13.09	198	310	1.86	16,709	3,188	19.08
Subarea 19, Sept.-Nov.	0	1,189	0	0	0	0	0	689	0	28,021	75	0	28,021	1,955	6.78
Mexico															
Inshore															
Laguna Madre, April-June	10,083	31	0.31	384	2	0.52	208	11	5.29	4	0	0	10,679	44	0.41
Offshore															
Subareas 22-24, May/Sept.	1,493	230	15.41	2,022	345	17.06	1	110	0	10	51	1.45	3,526	627	17.78
Subarea 24, June	5,094	794	15.59	525	85	16.19	0	0	0	0	27	0	5,619	906	16.12
Combined releases	47,827	3,122	6.52	14,596	2,402	16.46	2,050	1,167	56.93	48,488	492	0	112,961	7,183	6.35

Table 3.—Release and recapture summary for 1980 shrimp tagging studies.

Release area time	Brown			Pink			White			Spp. unknown			Totals		
	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%
Texas															
Inshore															
Port Isabel, Mar./April	2,912	230	7.90	9,448	1,296	13.72	0	0	0	3	7	0.06	12,363	1,533	12.40
Port O'Connor, May/July	10,218	8	0.08	0	0	0	0	2	0	0	0	0	10,218	1	0.10
San Luis Pass, June/July	11,350	1	0.01	0	0	0	0	0	0	0	0	0	11,350	1	0.01
East Galv. Bay, Sept./Oct.	0	2	0	0	0	0	5,141	355	6.94	0	0	0	5,141	359	6.98
Offshore															
Subarea 20, June/July	6,375	296	4.64	250	21	8.40	0	0	0	11	0	0	6,636	317	4.78
Subarea 20, May	721	128	17.79	3,271	906	27.70	0	1	0	11	0	0	4,003	1,035	25.86
Subarea 19, June/July	22,222	1,698	7.64	0	9	0	0	4	0	0	0	0	22,222	1,711	7.70
Subarea 18, Oct.	0	2	0	0	1	0	8,713	723	8.30	0	1	0	8,713	727	8.34
Mexico															
Inshore															
Laguna Madre, Mar./Apr./June	4,362	31	0.71	2,374	13	0.55	29	1	3.45	4	0	0	6,769	45	0.66
Offshore															
Subareas 22-23-24, May	4,983	1,053	21.13	3,895	529	13.58	0	0	0	21	0	0	8,899	1,582	17.78
Combined releases	63,143	3,449	5.46	19,238	2,775	14.42	13,883	1,088	7.84	50	8	0.01	96,314	7,320	7.60

catch statistics were also used to determine the proportion of pink shrimp in Texas commercial catches in the summer months.

Results and Discussion

Mark-Recapture

A total of 448,976 white, brown, and pink shrimp were released in U.S. and Mexican waters from 1978 to 1981, of which 28,505 were recaptured from 1978-81 (6.3 percent). Specific informa-

Table 4.—Release and recapture summary for 1981 shrimp tagging studies.

Release area time	Brown			Pink			White			Spp. unknown			Totals		
	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%	Rel.	Rec.	%
Texas															
Inshore															
Port O'Connor, Oct.	0	0	0	0	0	0	10,027	174	1.74	0	0	0	10,027	174	1.74
East Galv. Bay, May/June/Aug.-Oct.	15,375	691	4.51	0	0	0	20,272	809	3.99	0	0	0	35,647	1,502	4.21
Offshore															
Subarea 19, June-Oct.	40,474	5,394	13.33	0	0	0	14,306	421	2.94	0	1	0	54,780	5,816	10.62
Subarea 18, May/June/Oct./Nov.	35,074	219	0.62	0	0	0	34,784	2,636	7.58	0	0	0	69,858	2,855	4.09
Subarea 19, July	4,189	1,152	27.50	0	0	0	0	0	0	0	0	0	4,189	1,152	27.50
Mexico															
Offshore															
Subarea 34, March	0	0	0	9,656	239	2.48	10	0	0	0	0	0	9,666	239	2.47
Combined releases	95,112	7,458	7.84	9,656	239	2.48	79,399	4,040	5.08	0	1	0	184,167	11,738	6.37

tion on release area and time and numbers recaptured are provided in Tables 1-4. Most shrimp releases from inshore sites resulted in poor recoveries of less than 1 percent. The only notable exception was in 1980 at Port Isabel, Tex., when more than 12 percent of the shrimp released in March-April were recovered. We believe the reason for poor recovery rates for inshore sites is that techniques are not yet developed to tag large quantities of live shrimp properly during the periods when temperatures are notably high (i.e., >30°C) and water is clear which may increase mortality of tagged shrimp due to predation by major inshore predators (Howe and Hoyt, 1982).

Comparative tagging studies conducted in coastal Louisiana waters in the summer showed recovery rates ranging from 5.7 percent to 20.5 percent (Hollaway and Baxter, 1981; Baxter and Hollaway, 1981). The turbid waters in Louisiana probably prevented predation on tagged shrimp by major inshore predators. The combination of clear coastal Texas waters and high temperatures may have resulted in poor survival of the tagged shrimp. Further, inshore areas are probably not exposed to intensive fishing immediately following the release; therefore, the opportunity for recovery is slight and depends on shrimp migration to offshore waters where intensive fishereis are located. The water temperature at Port Isabel in March-April, when an inshore study was conducted, was well below 25°C and the shrimp appeared to be in good condition. In all other inshore studies, water temperatures were >25°C and shrimp condition was poor to fair.

Offshore recovery rates ranged from 2.5 percent in March 1980 on the Campeche Banks to 26 percent in the offshore fishery (statistical subarea 20) in May 1980. The low 2.5 percent recovery was probably due to poor detection of the tags and poor return of recaptured tagged shrimp to the proper authorities. This was the first mark-recapture study conducted on the Campeche Banks and, as such, the fishermen probably were not aware of the tags even though publicity of the tagging program had been distributed to the Campeche fleet. The next lowest recovery rate (4.2 percent) occurred from the October-November 1981 release in statistical subarea 18, probably due to low fishing pressure exerted in the area. Overall, recovery rates from the offshore fisheries reflected the fishing pressure exerted on the marked population. The offshore tagging studies conducted in 1978, 1979, and 1980 in the Tampico fishery (subareas 22-24) yielded consistently high recovery rates of 16-21 percent. This indicated a fairly consistent high rate of exploitation. On the other hand, the offshore tagging studies conducted off Texas yielded variable fishing intensity in time and space.

Shrimp Movement

Transboundary

Cody and Avent (1980) reported on the 1978-79 tagging studies conducted in Texas and described generalized movements of the shrimp stocks. We do not attempt to repeat their analyses but concentrate on the aspect of transboundary migration of brown and pink shrimp stocks.

A total of 108 brown and 160 pink shrimp were recaptured which had migrated either from the United States to Mexico or from Mexico to the United States. Movement of tagged brown shrimp from Mexico to the United States centered in statistical subarea 21. However, several of these shrimp migrated northward up the coast, one as far as long. 94°W and into waters deeper than 20 fm (Fig. 6). Most of the brown shrimp which moved from U.S. waters into Mexican waters were recovered immediately south of the border; however, one shrimp was recovered almost off Tampico and four were recovered south of lat. 24°N (Fig. 7).

Pink shrimp which moved across the

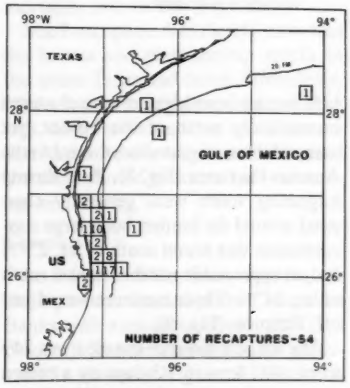

Figure 6.—Distribution of brown shrimp transboundary travelers, Mexico to Texas (number in grids 10 × 10 minutes).

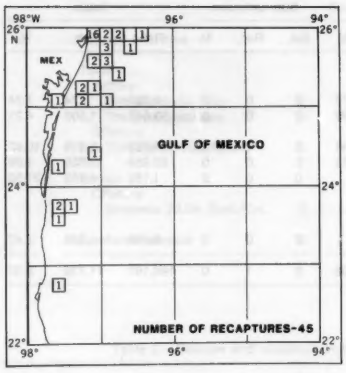

Figure 7.—Distribution of white shrimp transboundary travelers, Texas to Mexico (number in grids 10 × 10 minutes).

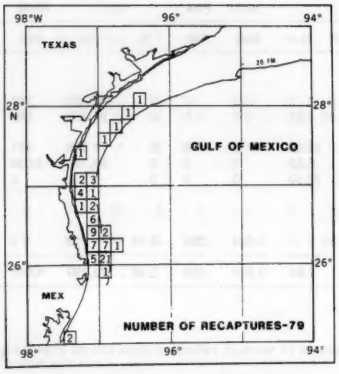

Figure 8.—Distribution of pink shrimp transboundary travelers, Mexico to Texas (number in grids 10 × 10 minutes).

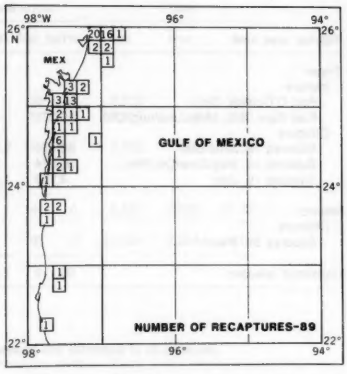

Figure 9.—Distribution of pink shimp transboundary travelers, Texas to Mexico (number in grids 10 × 10 minutes).

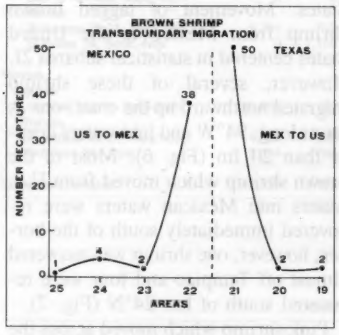

Figure 10.—Distribution of brown shrimp transbcundary travelers by statistical subareas.

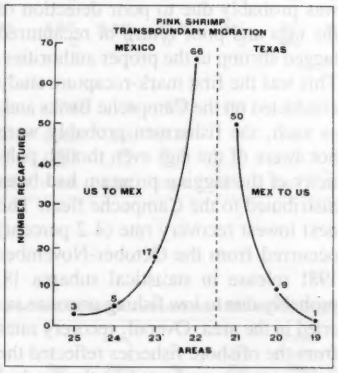

Figure 11.—Distribution of pink shrimp transboundary travelers by statistical subareas.

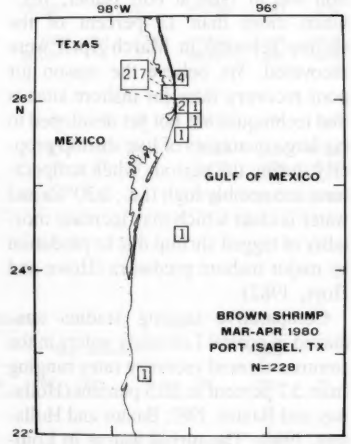

Figure 12.—Distribution of brown shrimp recoveries from Port Isabel, Texas shrimp tagging study, March-April 1980 (Grids are 10 × 10 minute intervals).

U.S. border from Mexico were clustered immediately north of the border, yet many of them migrated northward to the Aransas Pass area (Fig. 8). Pink shrimp migrating south were generally clustered around the border, but a large concentration was found south of lat. 25°N and an appreciable number moved south of lat. 24°N. Three were recovered just off Tampico (Fig. 9).

The longest distance traveled was 249 n.mi. (461 km) in 113 days by a brown shrimp released in August 1978. It had migrated from the U.S. statistical subarea 19 to statistical subarea 24 and had doubled its size. Eleven brown shrimp migrated over 200 n.mi. (370 km). Most recoveries of brown and pink shrimp were made in statistical subareas 21 and 22 (Fig. 10, 11) The longest time at large before recapture was 446 days for a pink shrimp which was released in Mexico and migrated only 27 n.mi. (50 km) northward across the U.S. border into statistical subarea 21. Forty-three shrimp were at large 100 days or longer. Most of the transborder migrants were released in offshore waters, but of 1,533 brown and pink shrimp recaptured from the Port Isabel tagging study (March-April 1980), 42 were recaptured in Mexico. Seven recaptured brown shrimp left the U.S. estuary and moved across the border, one as far as lat. 23°N (subarea 24, Fig. 12). None of the recaptured brown shrimp moved north. Pink shrimp migrated offshore to the north and south, with a large number being caught in the U.S. Laguna Madre

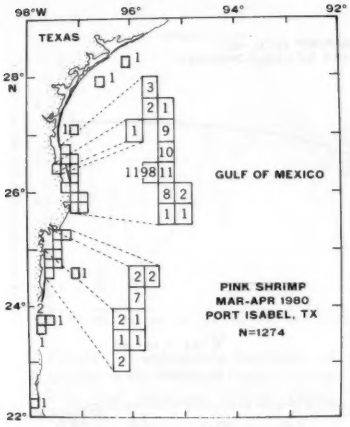

Figure 13.—Distribution of pink shrimp recoveries from Port Isabel, Texas shrimp tagging study, March-April 1980 (grids are 10 × 10 minute intervals).

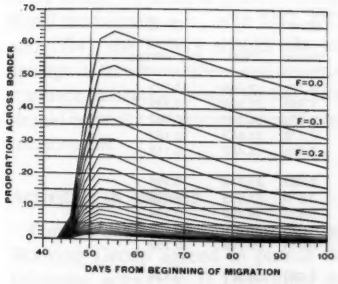

Figure 16.—Simulation of northward migration from Pass Jesus Maria, Mexico with F = 0.0-2.0 in increments of 0.1.

(Fig. 13). The farthest pink shrimp movement to the north was a recovery in statistical subarea 19 (1 shrimp), while 4 were recovered in statistical subarea 24. A total of 35 pink shrimp were recovered south of the U.S. border. Therefore, the Laguna Madre shrimp stock which utilized this nursery migrated offshore and into Mexican waters. Apparently brown shrimp move only southward, while pink shrimp move both north and south. The majority of the pink shrimp appeared to have moved south.

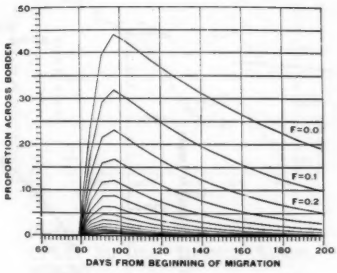

Figure 14.—Simulation of southward migration from Aransas Pass, Texas with F = 0.0-2.0 in increments of 0.1.

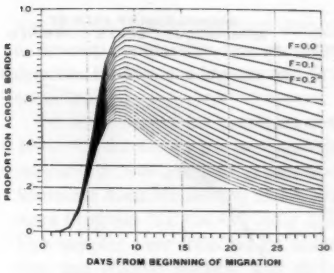

Figure 15.—Simulation of southward migration from Brazos Santiago Pass, Texas with F = 0.0-2.0 in increments of 0.1.

Figure 17.—Distribution of pink shrimp recoveries on the Campeche Bank (number in grids 10 × 10 minutes).

Brunenmeister's[2] model determined the proportion of the shrimp population which could cross the U.S.-Mexico border with assumed rates of fishing mortality. These data are presented in Figures 14, 15, and 16. She predicted that the shrimp population in Aransas Pass would take about 80 days to cross the border and, at fishing mortality rates of about 0.1, about 30 percent of the population would have crossed the border in 92 days (Fig. 15). For shrimp moving out of the Port Isabel area, assuming a fishing mortality rate of 0.1, about 90 percent of the population would move into Mexican waters in less than 10 days (Fig. 16). Northward migration from

[2]Brunenmeister, S. University of Maryland, Solomons, MD 20688; Personal commun.

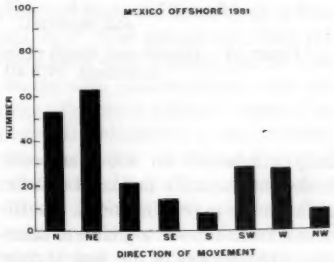

Figure 18.—Distribution of pink shrimp on the Campeche Bank by direction of movement.

Jesus Maria, Mex., would take half the population about 50 days to move across the U.S. border, assuming a fishing mortality rate of 0.1 (Fig. 16).

Mark-recapture data clearly show that the brown and pink shrimp stocks in the south Texas and north Tamaulipas, Mex., areas are migratory and cross the U.S.-Mexico border. One could assume that these stocks are continuous and therefore should be treated as one management entity.

Campeche

In March 1981, over 9,600 pink shrimp were released on the Campeche Banks with a recovery of only 238 (2.5 percent). The distribution of the recoveries is shown in Figure 17. Direction of movement was generally north-northeast with some movement to the south-south-west quadrants (Fig. 18). This was the first large-scale mark-recapture

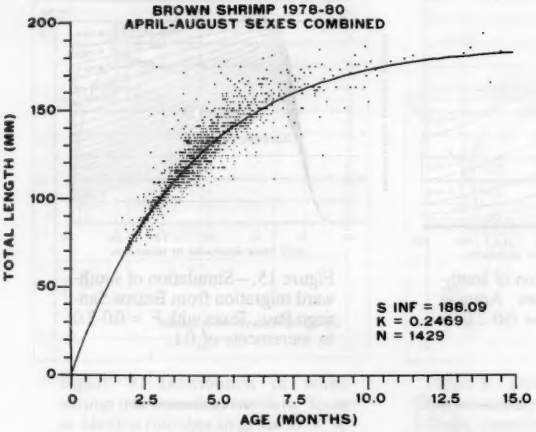

Figure 19.—Growth and length of brown shrimp, sexes combined, 1978-80.

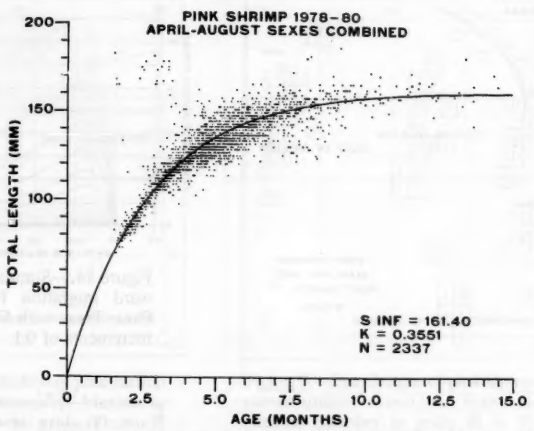

Figure 20.—Growth and length of pink shrimp, sexes combined, 1978-80.

study conducted on the Campeche Banks and basically indicated that the shrimp move in two directions. Insufficient information was available to determine growth rates of the pink shrimp stocks.

Growth

Growth and length for both brown and pink shrimp were estimated from 1978-80 combined data. The brown shrimp growth for the April-August period indicated an asymptotic length of about 188 mm (Fig. 19), whereas pink shrimp had an asymptotic length of about 161 mm (Fig. 20). These values compare favorably with an asymptotic length of 169 mm and 193 mm for males and females, respectively, developed by Parrack (1979) for brown shrimp.

Tampico Fishery

In 1979, U.S. and Mexican scientists agreed to a set of fishery statistics for the shrimp fishery in the Tampico area which included pounds landed and fishing effort (Table 5). These data formed a basis for evaluating the annual production for 23 years. Catches from 1974 to 1978 have been affected by limited U.S. fishing effort off Tampico. U.S. production decreased from 2,978 t in 1974 to 455 t in 1978. No fishing has been permitted since 1979. Total fishing effort decreased 66 percent from 1974 to 1978, resulting in a 50 percent decrease in the total catch (Fig. 21, 22). After detailed examination of these data, U.S. and Mexican scientists determined that conventional models, i.e., surplus production models, were not appropriate. Therefore, they felt the long-term average catch best represented a conservative approach to determine the available annual sustainable yield. Klima and Fuentes[3] concluded that the fishery

Table 5.—Summary of shrimp catch in metric tons, effort in days fished, catch per unit effort (CPUE) in tons/days (24 hours) of the United States and Mexico for the Tampico fishery.

	Catch (t)			Effort			CPUE
Year	U.S.	Mexico	Total	U.S	Mexico	Total	U.S.-Mexico
1956	4,464	601	5,065	16,125	2,171	18,296	0.277
1957	6,456	631	7,087	19,292	1,886	21,178	0.335
1958	5,079	482	5,561	31,292	2,970	34,262	0.162
1959	5,099	503	5,602	28,083	2,770	30,853	0.182
1960	1,664	426	2,090	14,667	3,755	18,422	0.113
1961	3,665	561	4,226	18,833	2,883	21,716	0.195
1962	2,757	621	3,378	17,625	3,970	21,595	0.156
1963	1,897	754	2,651	14,167	5,631	19,798	0.134
1964	2,356	646	3,002	14,417	3,953	18,370	0.163
1965	2,297	979	3,276	14,583	6,215	20,798	0.158
1966	2,777	1,128	3,905	19,917	8,090	28,007	0.139
1967	2,333	1,581	3,914	15,250	14,776	25,584	0.107
1968	3,683	1,803	5,486	21,750	10,648	32,398	0.169
1969	1,875	1,537	3,412	19,208	15,745	34,953	0.098
1970	2,370	2,705	5,075	20,167	23,018	43,185	0.118
1971	2,946	2,238	5,184	20,458	15,541	35,999	0.144
1972	3,919	3,172	7,091	20,250	16,390	36,640	0.194
1973	2,593	2,922	5,515	21,083	21,758	44,841	0.123
1974	2,978	3,110	6,088	13,166	19,768	32,934	0.185
1975	2,561	2,899	5,460	10,184	19,372	29,556	0.185
1976	538	3,450	3,988	3,830	20,374	24,204	0.165
1977	708	3,547	4,255	3,954	20,196	23,602	0.180
1978	455	2,561	3,016	2,988	18,417	21,094	0.143

[3]Klima, E. F., and D. Fuentes. 1979. Joint analysis of U.S.-Mexican Tampico shrimp fishery. NMFS Southeast Fisheries Center, Galveston Laboratory, 4700 Avenue U, Galveston, TX 77551. Unpubl. rep., 16 p.

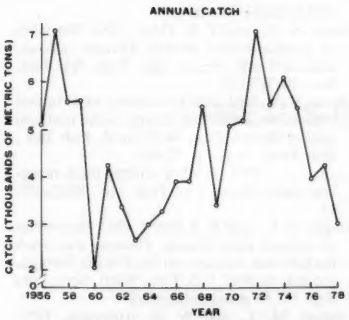

Figure 21.—Annual landings of shrimp in the Tampico fishery by the U.S. and Mexican fishing fleets, 1956-78.

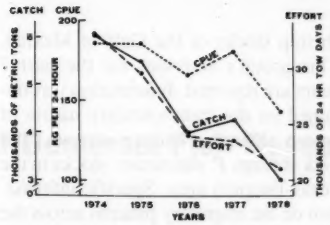

Figure 22.—Landings, effort and CPUE for the Tampico fishery, 1974-78.

could produce between 4,500 and 5,000 t per year, heads on, but that annual production fluctuates greatly, probably because of changes in fishing effort and recruitment. In times of good or exceptional recruitment (i.e., as in 1957, 1972, and 1974), the fishery should take advantage of this recruitment and optimize resource utilization, while fishing effort should be restricted during times of poor recruitment.

Activities in 1983-85

For the 1983-85 period, the Shrimp Working Group agreed to pursue the following activities: 1) Determine the species composition of commercial shrimp catches in the western Gulf of Mexico, 2) compare juvenile shrimp abundance in vegetated areas of Galveston Bay with those in the Mexican Laguna Madre, 3) conduct cooperative coastal surveys of shrimp and finfish to determine sizes, species compositions, and abundances in summer, and 4) determine trophic relationships of selected coastal fishes in offshore waters.

A report[4] on the misclassification of pink shrimp as brown shrimp in Texas commercial catches during summer months was completed. Pink shrimp were detected in about half the sampling trips and constituted 7-8 percent of the overall catches. Maximum proportions of pink shrimp were 41 percent of those landed in Galveston and 22 percent of those landed in Port Isabel in July. Proportions declined rapidly in later months.

A simple drop sampler and sampling methodology were developed for equivalent comparison of juvenile shrimp densities in vegetated and nonvegetated habitats of shallow water marshes and lagoons. The fundamental elements of the design were acquisition of real as opposed to relative densities of fishing species, and paired sampling of habitats (Zimmerman et al., 1984).

Quantitative drop sampler comparisons of *Spartina alterniflora*, *S. patens*, and *Halodule wrightii* nursery habitats have been acquired in Texas and Louisiana. Brown shrimp, white shrimp, blue crab, *Callinectes sapidus*; and some fishes are more abundant in vegetated areas than elsewhere (Zimmerman and Minello, 1984a; Zimmerman et al., 1984). Brown shrimp are equally abundant in adjacent *Spartina* and *Halodule* stands. Brown shrimp grew faster in vegetated areas than over bare substrates, while white shrimp grew at equal rates (Zimmerman and Minello, 1984b). Carbon isotope analyses indicated that brown and white shrimp feed on different types of food (Zimmerman and Minello, 1984b). Laboratory results indicated white shrimp were herbivorous while brown shrimp needed a mixed plant-animal diet.

Mexican officials participated in a demonstration of this estuarine sampling methodology at the SEFC Galveston Laboratory in June 1983. Discussion was initiated concerning joint research to develop comparable data on shrimp densities for Mexican lagoons and Texas estuaries.

The U.S. coast from Louisiana to the Texas-Mexico border has been surveyed annually in June and July as part of the Southeast Area Monitoring and Assessment Program (SEAMAP) since 1982. Fish samples were collected for maturation and trophic studies, and shrimp samples were collected for size distribution, species composition, sex and abundance analyses.

Trophic relationships of eight fish species were determined from samples collected along the Texas coast in June and July[5]. The species and their primary foods were: *Synodus foetens* - fish; *Ancylopsetta quadrocellata* - fish and crabs; *Prionotus tribulus* - crabs; *Centropristis philadelphica* and *Menticirrhus americanus* - crabs and shrimp; *P. rubio* and *Diplectrum bivittatum* - shrimp; *Lutjanus campechanus* - fish, crabs, and shrimp. Only three *Penaeus* were found in 4,300 stomachs examined. Only *Diplectrum* had entered a major spawning cycle at this time.

Future Direction

Since the implementation of the Shrimp Working Group in 1977, we have obtained good data on growth rates of both pink and brown shrimp, as well as preliminary information on the transboundary nature of the shrimp stocks. The 1977-81 large-scale tagging study called for releases of tagged shrimp dispersed in time and space. We now must estimate the flux of the brown shrimp stock across the Texas-Mexico border during the period peak migration, i.e., late May through mid-July. In the previous study, only 298 tagged shrimp were released off south Texas (statistical area 21) during this critical time period, with 14 recaptures from that release group (Sheridan et al., 1987).

The NMFS and INP will conduct cooperative mark-recapture experiments in south Texas and northern Mexico beginning in May 1985. Mexico will tag

[4]Slater, B. 1983. Report on misclassification of commercial pink shrimp as brown shrimp, July 16, 1982 to September 30, 1982. NMFS Southeast Fisheries Center, 75 Virginia Beach Dr., Miami, FL 33149. Unpubl. Rep., 33 p.

[5]Sheridan, P. F. NMFS Southeast Fisheries Center, Galveston Laboratory, 4700 Avenue U, Galveston, TX 77551; personal commun.

and release up to 20,000 shrimp off Tamaulipas, with assistance from NMFS personnel. Mexico will also collect tag returns and catch-effort statistics from the fishery. The NMFS will tag and release up to 100,000 shrimp at two Texas passes, Brazos-Santiago and Aransas; and offshore in subareas 20 and 21. Tag returns will be processed and catch-effort statistics will be collected and exchanged with Mexico.

The exchange of commercial catch statistics will continue between both countries. An effort will be made to obtain samples to simultaneously determine species composition of each country's commercial shrimp catch. U.S. and Mexican scientists will exchange collections of postlarval brown, white, and pink shrimps from Texas and Tamaulipas estuaries to verify identifications.

A major component of future studies will determine the importance of estuarine habitats, comparing those in Texas with the Mexican Laguna Madre. Specifically, we will examine the density of shrimp associated with the algae and marsh grasses, how density varies, and what factors may affect recruitment of juvenile shrimp to the estuaries and finally to the offshore fisheries.

Summary

A cooperative marine science research program was initiated between Mexico's Instituto Nacional de Pesca and the U.S. National Marine Fisheries Service's Southeast Fisheries Center in 1977. As part of that program, a shrimp working group was established to investigate the transboundary aspects of shrimp stocks of the Gulf of Mexico. This group's activities for the past 7 years are reported. Information was obtained on the transboundary nature of brown shrimp, *Penaeus aztecus*, and pink shrimp, *P. duorarum*, stocks in the Texas-Tampico area. Specific information on the migratory patterns across the U.S.-Mexico border are described. Growth of brown and pink shrimp for the period April-August are also described and information is presented on the status of the Tampico fishery. Proposed plans for future research include a continued exchange of catch and effort statistics, studies to determine the importance and recruitment patterns of estuarine systems, both in the United States and Mexico, and a tagging experiment during peak brown shrimp emigration, May-July 1985.

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MEXUS-Gulf Demersal Fish Research, 1978-85

ELMER J. GUTHERZ

Introduction

The MEXUS-Gulf concept was conceived to enhance an understanding of the fisheries and ecology of shared resources in the Gulf of Mexico. Discipline oriented working groups including the demersal fish group were established at the initial meeting of MEXUS-Gulf. Emphasis was first placed on fish stocks off the Yucatan Peninsula; however, in subsequent meetings research efforts were directed to stocks of deep-water species of snapper, grouper, and tilefish throughout the Gulf of Mexico.

Activities within the demersal fish working group have changed but overall goals remained constant. Defined goals were to: 1) Obtain data on distribution and abundance of deep-water snapper, grouper, and tilefish stocks; and 2) obtain data on biomass and faunal components of trawl caught species off the Yucatan Peninsula. These goals have been pursued by scientific personnel and vessels from Federal research organizations of Mexico (Secretaria de Pesca's Instituto Nacional de Pesca—INP) and the United States (National Marine Fisheries Service—NMFS). This report is presented in two parts, the first providing a faunal inventory of trawl-caught species off Mexico (Yucatan Peninsula to Tamaulipas) and the second addressing distribution and abundance of snapper, grouper, and tilefish in deep water.

Methods

Gulf of Mexico data pertaining to MEXUS-Gulf objectives were collected aboard both INP and NMFS vessels. Cruises satisfying defined annual objectives are listed in Table 1, and cover the entire Gulf of Mexico. Efforts expended are shown in Figures 1 (trawling) and 2 (longlining). Trawling data was collected using a 12 m semiballoon shrimp trawl with 2.4 × 1.0 m wooden chain doors on the *Oregon II* and a 14 m western jib trawl with 2.1 × 0.9 m wooden chain doors on the MV *Onjuku*. Longline data was collected with standard 2-hour sets using 377 m of mainline fished with 100 number 6 and 7 Japanese circle tuna hooks on the *Oregon II*; and 960 m of mainline with 200 number 6 and 7 Japanese circle tuna hooks on the MV *Onjuku* (Gutherz et al.[1]). Limited use was made of data obtained at several handline stations. Data collected included species identification to the lowest taxon, number of specimens caught, aggregate weight of the species caught, and length frequency information on predefined species. Biological data was obtained on sex and maturation stage; scales and/or otoliths were collected for population data from grouper, snapper, and tilefish. Limited environmental and habitat information was collected to broadly define habitats utilized by defined species.

Table 1.—Cruises operating under MEXUS-Gulf auspices (demersal fish working group) from 1979 to 1983 from which faunal data was obtained.

Vessel	Date	Area	Operation
Oregon II	June 1979	Tampico to Texas	Trawls-shrimp tagging
Oregon II	Aug. 1979	Northern Yucatan	Trawls and longlines
Oregon II	Sept. 1979	Tampico to Texas	Trawls-shrimp tagging
Oregon II	May 1980	Southern Yucatan	Trawls-shrimp tagging
Oregon II	Sept. 1980	Northwestern Yucatan	Trawls and longlines
Onjuku	Aug. 1981	Veracruz to Carmen	Trawls and longlines
Oregon II	Aug. 1983	Offshore Texas	Trawls and longlines
Oregon II[1]	Oct. 1979	Tampa to Tortugas, Fla.	Longlines
Oregon II[2]	Sept. 1984	Offshore Texas	Submersible-longlines

[1]Areal coverage requested at MEXUS-Gulf meeting.
[2]Not under direct MEXUS-Gulf auspices.

Longline catch rates were computed to establish indices of relative abundance throughout the entire Gulf of Mexico for snapper, grouper, and tilefish; sharks were generally weighed only after identification. Catch by area was standardized to a catch rate of kilograms per 100 hooks per hour for each bottom longline set. Data was then summarized and mean catch rates per 0.5° blocks computed. Standardized catch rates were also summarized by faunal zones (Fig. 3) and depth; a mean catch rate and its associated confidence interval was then computed for each unit (Table 2). Other species caught on the longlines were identified and their weights recorded.

Trawl catches were processed separ-

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[1]Gutherz, E. J., M. Contreras, A. J. Kemmerer, B. A Rohr, W. R. Nelson, and V. Morano. 1982. A summary of Mexus-Golfo cooperative demersal fish research 1978-1982. Report submitted to Southeast Fisheries Center (NMFS) and Instituto Nacional de Pesca (INP). Memora de la VII Reunion Mexus-Golfo, Veracruz, 24-26 de Agosto, 1982, 11 p.

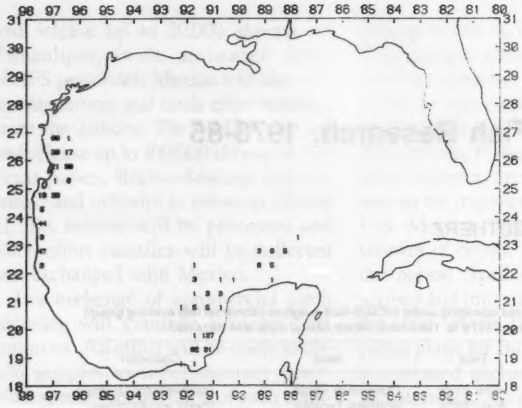

Figure 1.—Trawl stations on MEXUS-Gulf cooperative cruises between 1979 and 1983.

Figure 2.—Bottom longline effort as number of sets per 0.5 degree blocks in depths exceeding 90 m; data sets obtained on the *Oregon II* and *Onjuku* from 1968 to 1984.

ately with catches weighing less than 25 kg handled in their entirety. Larger catches were sampled, although the entire catch was weighed to the nearest 0.5 kg.

Selection of sample stations during shrimp tagging cruises was based on abundance of shrimp, and they were not randomized. All other trawl stations were randomly selected (Gutherz et al.[1]).

Longline stations were selected randomly according to predetermined, area, depth strata, and day/night periods with sampling restricted to between 90 and 460 m. During cruises, modifications to the sampling schemes were required due to bottom conditions which precluded some sampling at predetermined stations.

Trawling Results

Trawling results have been compiled and are presented in Gutherz et al.[1] Faunal listing and biomass estimates are included for off the Yucatan Peninsula and Tamaulipas. Overall, the tomtate, *Haemulon aurolineatum*, was the dominant trawl-caught finfish and the pink shrimp, *Penaeus duorarum*, was the dominant invertebrate (Table 3). The 20 dominant species taken at all trawling stations are listed in Table 3. Trawling data was separated into three distinct geographical areas which have unique biological and geomorphic characteristics.

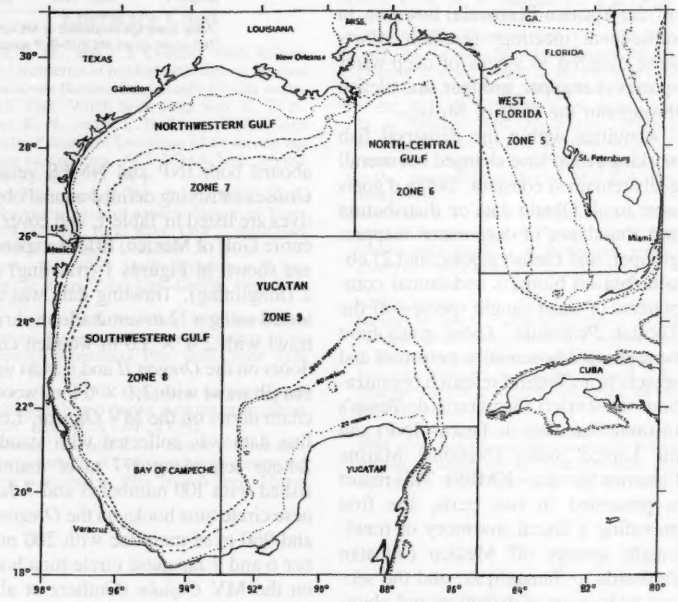

Figure 3.—Faunal zones used for summarization of Gulf of Mexico bottom longline data from 90 to 455 m.

The northern Yucatan area features a limestone substrate upon which sponge and patch corals form a live bottom habitat which is difficult to sample with trawls. Within this habitat night catches were about three times higher than day tows (203 vs. 71 kg/hour). Yellow goatfish, *Mulloidichthys martinicus*, and

Table 2.—Mean catch rate and confidence interval expressed as kg/100 hooks/hour for Gulf of Mexico faunal zones in depths exceeding 90 m.

Species	Faunal zones 5 N = 18 sets	6 N = 33 sets	7 N = 120 sets	8 N = 10 sets	9 N = 116 sets
Epinephelus flavolimbatus	0.00 ± 2.95	3.61 ± 2.8	2.01 ± 1.14	7.09 ± 3.96	4.14 ± 1.16
Lutjanus campechanus	0.34 ± 0.96	0.11 ± 0.71	0.13 ± 0.37	4.14 ± 1.28	1.44 ± 0.38
Etelis oculatus	0.00 ± 1.79	0.00 ± 1.32	0.02 ± 0.69	0.00 ± 2.40	0.08 ± 0.70
Caulolatilus microps	0.17 ± 0.37	0.00 ± 0.28	0.004 ± 0.14	0.00 ± 0.50	0.41 ± 0.15
Epinephelus niveatus	0.00 ± 1.16	0.00 ± 0.85	0.25 ± 0.45	0.23 ± 1.55	0.35 ± 0.46
Lopholatilus chamaeleonticeps	0.06 ± 3.13	2.45 ± 2.31	11.76 ± 1.21	0.50 ± 4.20	1.34 ± 1.23

Table 4.—Percent of bottom longline sets fished in the Gulf of Mexico by depth category, 1967-1982.

Area (faunal zones)	Depth (m) 90-180 m Percent	90-180 m No. of sets	182-271 m Percent	182-271 m No. of sets	273-362 m Percent	273-362 m No. of sets	364-455 m Percent	364-455 m No. of sets	Total Percent	Total No. of sets
Western Florida (Zone 5)	2	6	2	6	1	4	1	2	5	18
North-central Gulf (Zone 6)	2	7	3	9	3	10	2	7	10	33
Northwestern Gulf (Zone 7)	3	10	6	20	23	70	6	21	37	121
Southwestern Gulf (Zone 8)	5	17	1	4	1	2	0	0	7	23
Yucatan (Zone 9)	23	74	9	30	5	16	4	13	41	133
Total	35	114	21	69	31	102	13	43	100	328

Table 3.—Twenty dominant species from 524 MEXUS-Gulf shrimp trawl stations (5,736 kg) as percent total weight of the catch. Samples were taken from the southwestern Gulf of Mexico and off the Yucatan Shelf in 15-73 m.

Common and scientific name	Percent weight
Finfishes	
Tomtate, *Haemulon aurolineatum*	5.1
Pinfish, *Lagodon rhomboides*	2.0
Inshore lizardfish, *Synodus foetens*	1.5
Longspine porgy, *Stenotomus caprinus*	1.5
Dusky flounder, *Syacium papillosum*	1.3
Bigeye, *Priacanthus arenatus*	1.3
Flounder, *Syacium* sp.	1.2
Hardhead catfish, *Arius felis*	1.2
Gray angelfish, *Pomacanthus arcuatus*	1.1
Yellow goatfish, *Mulloidichthys martinicus*	1.1
Other fishes	31.8
Subtotal	49.1
Crustaceans	
Pink shrimp, *Penaeus duorarum*	13.2
Blue crab, *Callinectes similis*	6.5
Mantis shrimp, *Squilla* sp.	5.6
Brown shrimp, *Penaeus aztecus*	4.6
Blue Crab, *Callinectes rathbunae*	2.0
Trachypeneus sp.	1.7
Rock shrimp, *Sicyonia brevirostris*	1.1
Other crustaceans	3.9
Subtotal	38.6
Other species	
Sponge, Porifera	3.8
Long-finned squid, *Loligo pealei*	1.8
Sea cucumber, Holothuroidea	1.5
Other species	5.2
Subtotal	12.3

tomtate were the principal species caught. Day/night catch rates of yellow goatfish were similar, suggesting a relatively consistent diurnal behavior pattern, but nighttime catch rates of tomtate were about six times higher than day catches. Tomtates have been reported to leave reef sites during night hours to forage on the grass and sand flats off the reef. This behavior would make tomtates much more susceptable to trawls during night hours. Inshore (<36 m) and offshore (>36 m) differences in catch rates were also noted with tomtate; pluma, *Calamus pennatula*; and sand perch, *Diplectrum formosum*, caught most frequently inshore, and tomtate, yellow goatfish, and pinfish, *Lagodon rhomboides*, caught most frequently offshore. These five species accounted for between 31 and 43 percent of the total catch off the northern Yucatan Peninsula. Species obtained off the northern Yucatan Peninsula numbered 124 from the 28 trawl samples. This is fewer than identified from the other two areas but does not necessarily indicate a reduced species diversity. The difficulty in sampling the habitat is undoubtedly responsible for the reduced number of species caught.

The western Yucatan area is composed of a limestone substrate with some sponge and patch coral in its northern portion and a sand/shell/mud substrate in the southern portion. Catch rates were generally low throughout the western Yucatan with day catches higher (53 vs. 34 kg/hour). Dominant day-caught species were all finfish, including gray angelfish, *Pomacanthus arcuatus*; lane snapper, *Lutjanus synagris*; and Campeche porgy, *Calamus campechanus*; dominant night-caught species included two crustaceans (pink shrimp and blue crab, *Callinectes* sp.) and one finfish (tomtate).

Inshore-offshore differences were also quite distinct with three species of crustaceans dominant inshore and three species of finfish dominant offshore. Inshore species included brown shrimp, *Penaeus aztecus*; blue crab, and mantis shrimp, *Squilla* sp.; offshore species included tomtate, dwarf goatfish, *Upeneus parvus*; and spotfin mojarra, *Eucinostomus argenteus*. Species diversity off the western Yucatan Peninsula is reflective of its two major habitats. Identified species numbered 193 taken on the 250 stations sampled. Dominant species were taken on both the live bottom and sand/shell habitat.

The western Gulf (off Tamaulipas) is composed of primarily sand/shell/mud substrate. Samples were taken only at night; however, catch rates were generally quite low, averaging only 33 kg/hour. Major differences were encountered between inshore-offshore catches in terms of speciation. Inshore stations caught 140 species whereas offshore stations caught only 40. Dominant inshore species included pink, brown, and mantis shrimp, and dominant offshore species included brown shrimp, blackear bass, *Serranus atrobranchus*; and inshore lizardfish, *Synodus foetens*. Identified species in the western Gulf numbered 141 from the 246 stations sampled and represent a faunal component which is similar to that seen on the brown shrimp grounds off Texas in the northern Gulf of Mexico. Faunal components and their respective biomass caught off Mexico were reported by Gutherz et al.[1]

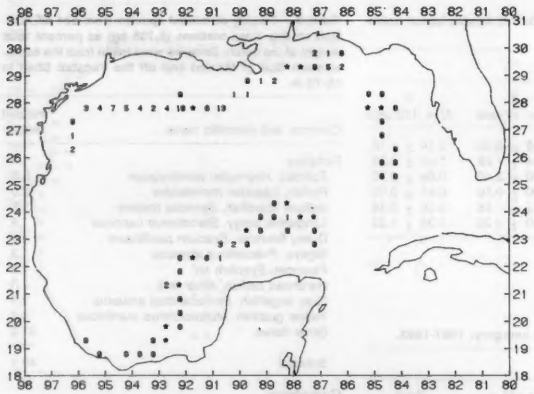

Figure 4.—Catch rate of golden tilefish expressed as kg/100 hooks/hour using bottom longlines in depths exceeding 90 m; data sets obtained on the *Oregon II* and *Onjuku* from 1968 to 1984. A star represents catches of less than 0.5 kg/100 hooks/hour.

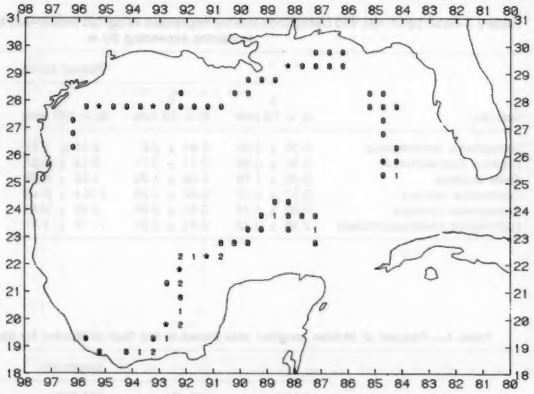

Figure 5.—Catch rate of snapper (primarily red snapper) expressed as kg/100 hooks/hour using bottom longlines in depths exceeding 90 m; data sets obtained on the *Oregon II* and *Onjuku* from 1968 to 1984. A star represents catches of less than 0.5 kg/100 hooks/hour.

Longlining Results

Considerable effort has been expended utilizing on- and off-bottom longlines in the Gulf of Mexico to evaluate the resource potential and status of snapper-grouper-tilefish stocks. Of the total effort devoted to this endeavor only a small portion was in response to MEXUS-Gulf requests. Data from all MEXUS-Gulf cooperative cruises has been shared jointly, with the United States taking the lead role in the analysis of distributional and relative abundance patterns for snapper-grouper-tilefish. Relative population levels of these species for each faunal zone (Table 2) was estimated using fishery independent catch rates to determine the mean catch rate and its associated confidence interval.

Longline efforts have been exerted throughout most of the Gulf of Mexico (Fig. 2). Notable for its lack of any data is the area from off Vera Cruz to the U.S.-Mexican border. Major effort has been expended off Texas and the Yucatan Peninsula (Fig. 2, Table 4). The U.S. Gulf of Mexico has fairly broad coverage in terms of number of sets made, but additional effort should be expended in the eastern Gulf of Mexico. In terms of depth coverage, the shallowest and intermediate depths were well sampled, but the deepest depths appear to be somewhat undersampled (Table 4).

Catch rates of snapper-grouper-tilefish stock throughout the Gulf of Mexico are variable (Tables 2, 5; Fig. 4-7). Tilefish, *Lopholatilus chamaeleonticeps*, were caught at the lowest rate throughout the Gulf of Mexico, except for faunal zones 6 and 7 (Tables 2, 5; Fig. 4). The broadest shelf in those depths at which tilefish are found is along the northern Gulf of Mexico (Faunal zones 6 and 7). Tilefish are generally found on mud bottoms which have a consistency enabling the species to construct and maintain its burrow. Periodically the species is also found over irregular bottom contours in association with grouper, *Epinephelus* spp., and blueline tilefish, *Caulolatilus microps*. At a single site off the northern Yucatan Peninsula, three species (tilefish, blueline tilefish, and yellowedge grouper, *E. flavolimbatus*, were captured on the same set. At four sites off the northern Yucatan Peninsula, blueline tilefish and yellowedge grouper were captured together, and at a total of 28 sites tilefish and yellowedge grouper were captured together (21 in the northern Gulf of Mexico and 7 off the Yucatan Peninsula). These combined captures of grouper and tilefish suggest utilization of similar habitats or multiple habitats within close proximity to each other. Burrow utilization by specimens of these three species has been reported (Jones et al.[2]; Able et al., 1982; In press). Collection of these two or three species on the same set may

Table 5.—Percent composition of catch by family of deep-water reef fish taken on bottom longlines in depths of 90-455 m by faunal zone in the Gulf of Mexico (from Nelson, et al.[1]: Table 9).

Family	Faunal zone 5	6	7	8	9	Mean %
Lutjanidae	10.7	1.2	1.0	28.7	17.4	12.7
Serranidae	35.7	21.2	16.7	41.5	39.3	30.8
Branchiostegidae	7.1	14.1	54.9	2.9	9.7	14.7
Sharks	35.7	46.5	19.6	16.0	25.8	31.9
Others	10.8	15.3	7.8	11.7	7.7	9.9
Total[2]	100.0	100.0	100.0	100.0	100.0	100.0

[1]Nelson, W. R., G. M. Russell, and E. J. Gutherz. 1982. Status of reef fish resource survey activities of the Southeast Fisheries Center. A special report for the Southeast Fisheries Center 1982 stock assessment workshop; on file at SEFC Mississippi Laboratories, Pascagoula Laboratory, Pascagoula, Miss., 46 p.

[2]Values may not add to exactly 100.0 due to rounding.

[2]Jones, R. S., W. R. Nelson, and E. J. Gutherz. 1986. Exploitation of burrow habitats by the yellow-edge grouper (*Epinephelus flavolimbatus*). Manuscr. with R. Jones, Univ. Tex. Mar. Sta., Port Aransas, Tex.

Figure 6.—Catch rate of grouper expressed as kg/100 hooks/hour using bottom longlines in depths exceeding 90 m; data sets obtained on the *Oregon II* and *Onjuku* from 1968 to 1984. A star represents catches of less than 0.5 kg/100 hooks/hour.

Figure 7.—Catch rate of yellowedge grouper expressed as kg/100 hooks/hour using bottom longlines on the *Oregon II* and *Onjuku* from 1968 to 1984. A star represents catches of less than 0.5 kg/100 hooks/hour.

also indicate occupation of the same burrow or burrows within close proximity to each other.

Species in the family Lutjanidae are most frequently caught in depths less than 90 m. The outer depths at which red snapper, *Lutjanus campechanus*, were generally caught was about 136 m. Species of snapper generally caught at greater depths are the blackfin snapper, *L. buccanella*; silk snapper, *L. vivanus*; and queen snapper, *Etelis oculatus*; however, these species were caught infrequently. Rates of capture were generally low for Lutjanidae throughout the Gulf of Mexico, with the highest rates off Mexico in faunal zones 8 and 9 (Tables 2, 5; Fig. 5).

Serranids (*Mycteroperca* and *Epinephelus*) were caught throughout the Gulf of Mexico. The primary species captured in depths greater than 90 m was the yellowedge grouper. Although caught throughout the Gulf of Mexico it was taken most frequently in faunal zones 8 and 9 (Tables 2, 5; Fig. 6, 7). The snowy grouper, *E. niveatus*, was the second most frequently caught deepwater serranid. Groupers caught in faunal zones 5 and 9 were generally caught on rough bottom which has topographic highs as opposed to the smoother substrate frequently found in faunal zones 6 and 7. Depth preference of groupers is inshore of tilefish and offshore of snapper species.

Within the Gulf of Mexico, shark species were more frequently caught than either snapper-grouper or tilefish. Species of shark caught were varied and consisted of both large and small species. Many of the large *Carcharhinus* species were exploited and utilized; however, other genera and species are frequently discarded.

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MEXUS-Gulf Coastal Pelagic Fish Research, 1977-84

EUGENE L. NAKAMURA

Introduction

The major goal of the MEXUS-Gulf Coastal Pelagics Working Group has been to determine whether coastal pelagic fishes, with emphasis on Spanish mackerel, *Scomberomorus maculatus*, and king mackerel, *S. cavalla*, fished by both Mexico and the United States, comprise a single stock or separate stocks. Accomplishments to attain this goal during 1977-84 consisted of cooperative tagging studies, cooperative tissue sampling for electrophoretic studies, exchange of data and publications, and consultations between biologists of the two countries. Results of the tagging and electrophoretic studies are summarized briefly below.

Mackerel Tagging

Marking, or tagging, fish has long been a practical method of determining movements of fish and making inferences on stock identity. More than 8,000 fish have been tagged and released in the Gulf of Mexico, primarily off Veracruz in Mexico and off Panama City and Grand Isle in the United States (Tables 1, 2). Over 12,000 king mackerel have been tagged and released off the U.S. Atlantic coast by the Florida Department of Natural Resources (Williams and Godcharles[1]). Results of tagging mackerels in the Gulf of Mexico have been summarized by Williams and Sutherland (1979), Sutherland and Fable (1980), Vasconcelos[2], and Ramirez et al.[3]

Two types of tags were used. An anchor tag with a small plastic disc inserted into the pterygiophores was used on Spanish mackerel, while a similar tag but with a slightly larger plastic disc was inserted into the abdominal cavity of

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Table 1.—Coastal pelagic fishes tagged and released in the northern U.S. Gulf of Mexico, MEXUS-Gulf, 1977-84.

Species	No. tagged and released								
	1977	1978	1979	1980	1981	1982	1983	1984	Total
Spanish mackerel, *Scomberomorus maculatus*	262	0	14	240	0	0	28	4	548
King mackerel, *S. cavalla*	631	102	9	8	0	0	1,457	191	2,398
Little tunny, *Euthynnus alletteratus*	0	0	453	1,707	0	0	0	0	2,160
Bluefish, *Pomatomus saltatrix*	0	0	223	145	0	518	360	0	1,246
Blue runner, *Caranx crysos*	0	0	0	0	0	0	135	0	135
Ladyfish, *Elops saurus*	0	0	45	303	0	0	0	0	348
Atlantic bonito, *Sarda sarda*	0	0	63	1	0	0	0	0	64
Dolphin, *Coryphaena hippurus*	0	0	49	38	0	0	0	0	87
Greater amberjack, *Seriola dumerili*	0	0	0	2	0	0	0	0	2
Total	893	102	856	2,444	0	518	1,980	195	6,988

[1]Williams, R. O., and M. F. Godcharles. 1984. Completion report. King mackerel tagging and stock assessment. Project 2-341-R. Presented at Stock Assessment Workshop, Miami, Florida, June 1984. SAW/84/GCP/4.

[2]Vasconcelos, J. 1980. Preliminary aspects on migration of Spanish mackerel in the Gulf of Mexico coast. Paper presented at MEXUS-GULF V, Tampico, Mexico, Oct. 1980.

[3]Ramirez, E., J. Vasconcelos, and D. Mendizábal. 1982. Reporte del grupo pelagicos-costeros, I.N.P., Mexico, 1977-1982. Report presented at MEXUS-GULF VII, Veracruz, Mexico, Aug. 1982.

Table 2.—Coastal pelagic fishes tagged and released in the Mexican Gulf of Mexico, MEXUS-Gulf, 1978-83.

Species	No. tagged and released						
	1978	1979	1980	1981	1982	1983	Total
Spanish mackerel	147	314	564	0	16	0	1,041
King mackerel	0	85	0	0	19	0	104
Little tunny	0	0	1	0	58	0	59
Blue runner	0	0	0	0	3	0	3
Yellowfin tuna, *Thunnus albacares*	0	0	0	0	1	0	1
Total	147	399	565	0	97	0	1,208

Table 3.—Data on recovered fish that demonstrated international migration.

Species	Release location	Release date	Recovery location	Recovery date	Days out	Direct distance (km)
Spanish mackerel	Port Aransas, Texas	9/29/75	Veracruz, Veracruz	1/2/76	96	900
King mackerel	Naples, Florida	3/20/76	Isla Arenas, Yucatan	7/28/77	495	1,000
King mackerel	Fort Pierce, Florida	1/18/78	Veracruz, Veracruz	9/14/78	239	1,930
King mackerel	Veracruz, Veracruz	10/30/79	Port O'Connor, Texas	7/4/81	613	965
King mackerel	Grand Isle, Louisiana	12/13/83	Veracruz, Veracruz	3/13/84	91	1,200

king mackerel (Sutherland and Fable, 1980). Both tags (Fig. 1) had plastic tubing trailing externally. Posters describing the tags and announcing a reward for the recapture information and tag were distributed in both Mexico and the United States.

Recoveries in U.S. waters of king mackerel that were tagged and released in the U.S. Gulf of Mexico indicated that in the eastern Gulf these fish move north in the spring and spend their summer in the northern Gulf, then return south in the fall to spend their winter in south Florida (Sutherland and Fable, 1980, Williams and Godcharles[1]). King mackerel that have been tagged and released off Louisiana in the winter have moved westward; of about 20 recoveries of the more than 1,500 released fish, none has been recovered east of the Mississippi River.

Only one recovery in Mexican waters of a king mackerel tagged and released in Mexican waters has been recorded (Ramirez et al.[3]). This fish was one of the 70 that were tagged and released off Veracruz by biologists of the Florida Department of Natural Resources and the Instituto Nacional de Pesca. It was recovered off Progreso, Yucatan, a distance of about 800 km from Veracruz and had been at liberty for 434 days (released 31 October 1979, recovered 7 January 1981[1]).

Recoveries in U.S. waters of Spanish mackerel that were tagged and released in the northeastern Gulf off Panama City, Fla., have shown a westward spring migration (Sutherland and Fable, 1980); recoveries in Mexican waters of Spanish mackerel tagged and released off Veracruz, Veracruz, indicate a northern spring migration and southern fall migration (Vasconcelos[2], Ramirez et al.[3]).

Thus far, recoveries of four king mackerel and one Spanish mackerel have indicated international migration (Table 3). Three king mackerel tagged and released in U.S. waters have been recovered in Mexican waters, and one king mackerel tagged and released in Mexican waters has been recovered in U.S. waters (Fig. 2). One Spanish mackerel that was tagged and released off Port Aransas, Tex., in 1975 (prior to the formation of MEXUS-Gulf) was recovered off Veracruz, Veracruz, 3 months later (Fig. 2). Data from these five recoveries are obviously insufficient to draw conclusions. Cooperative tagging, therefore, is continuing with a concerted

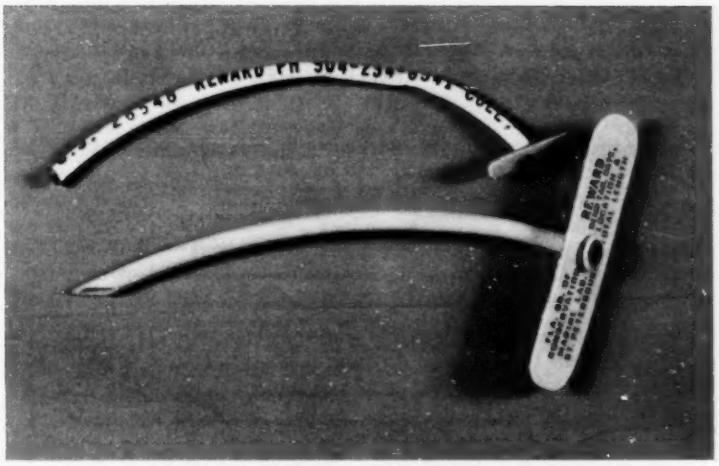

Figure 1.—Tags used in marking king and Spanish mackerels. Tag with message on plastic tubing was used on Spanish mackerel. Tag with message on disc was used on king mackerel.

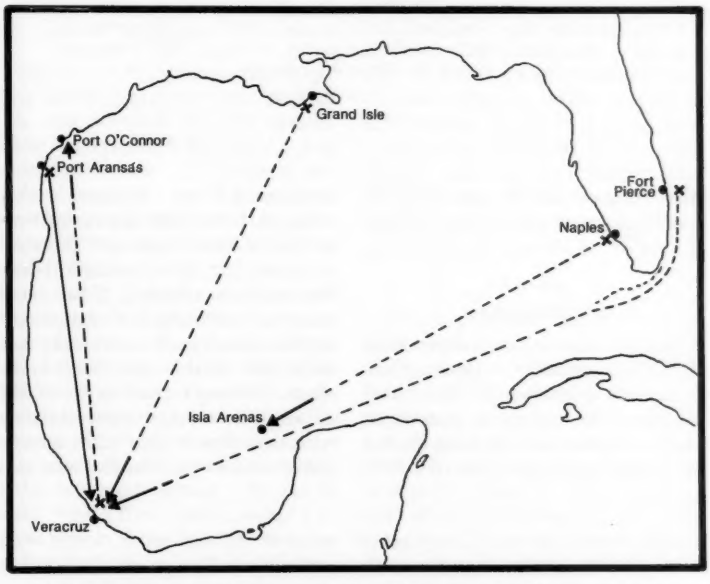

Figure 2.—Direct paths between release and recapture sites of king mackerel (dashed lines) and Spanish mackerel (solid lines). See Table 3 for details.

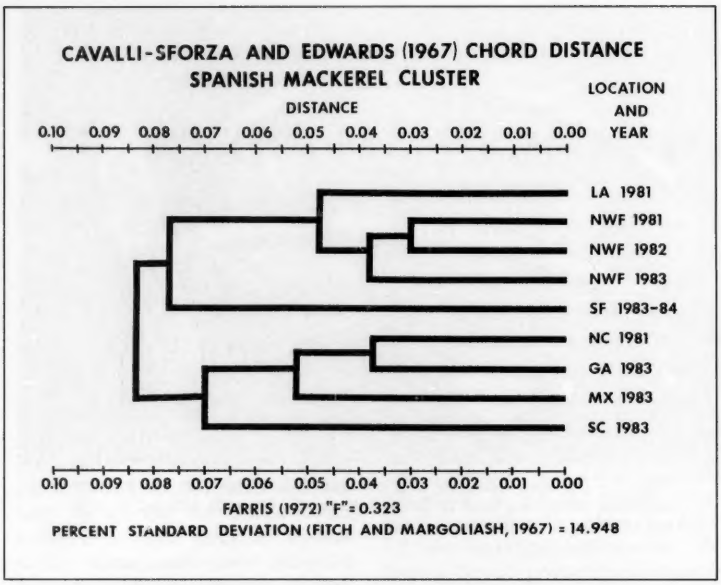

Figure 3.—Cluster dendrogram of results of electrophoretic analyses of muscle enzymes from Spanish mackerel. LA = Louisiana, NWF = northwest Florida, SF = south Florida, NC = North Carolina, GA = Georgia, MX = Veracruz, and SC = South Carolina. See Table 4 for details.

effort to tag and release more fish in the northwestern and southwestern sectors of the Gulf of Mexico.

Electrophoresis

Electrophoresis has been shown to be a promising method of analyzing genetic variants of proteins for stock identification. Electrophoretic analyses of muscle enzymes have been conducted on Spanish mackerel from six U.S. localities and one Mexican locality (Table 4). Over 2,000 specimens from the Gulf of Mexico and the U.S. Atlantic coasts have been examined. Forty-four loci were examined; 22 percent of these were polymorphic. Common variants were found in six muscle enzymes, while rare variants were found in six others. Although frequencies of the variants were not significantly different between groups of fish, minor genetic differences between localities were suggested by cluster analysis of the data (Fig. 3). Two major groups were suggested, one along the Georgia-Carolina coast and another in the northeastern Gulf (Louisiana-northwest Florida). The Mexican and South Carolina samples, which were few in number (Table 4), clustered with the Georgia-Carolina group. This suggests that Spanish mackerel from Veracruz may belong to a third group. Sampling in Mexico and in Texas will be emphasized in this continuing cooperative research.

Table 4.—Samples of Spanish mackerel collected from the southeastern United States and Mexico for electrophoretic examination, 1981-84.

Location	Sampling dates	Length range[1]	Number of fish
Louisiana	Apr. 1981 and Aug. 1981	350-450	138
Northwest Florida	Apr. 1981 to Oct. 1981	350-450	295
	Mar. 1982 to Oct. 1982	350-450	281
	Apr. 1983 to Sept. 1983	250-450	305
North Carolina	Aug. 1981 and Nov. 1981	200-300	597
Georgia	May 1983	250-400	167
Mexico (Veracruz)	Oct. 1983	350-550	53
South Florida	Dec. 1983 and Jan. 1984	450-550	140
South Carolina	Oct. 1983	150-180	50

[1]Fork length in millimeters.

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MEXUS-Gulf Ichthyoplankton Research, 1977-84

WILLIAM J. RICHARDS

Introduction

The Ichthyoplankton Working Group is one of the original working groups established at the founding of MEXUS-Gulf. The objectives of the working group have undergone little change over the past nine years and the results have advanced our understanding of the Gulf of Mexico. Basic ichthyoplankton studies entail the collection of plankton samples from the sea. These samples are then analyzed to provide: 1) Fishery-independent estimates of spawning stock size, 2) information on distribution and abundance of eggs and larvae of fish, 3) information on kinds of fish spawning, and 4) information on habitat preferences of the early life history of fish. This paper describes the objectives, methods, and accomplishments of the Ichthyoplankton Working Group since the establishment of MEXUS-Gulf.

Objectives

The continuing objective of the Ichthyoplankton Working Group has been to assess the biomass of major fishery resources of the Gulf of Mexico by the fishery-independent method of cooperative ichthyoplankton surveys. Specific objectives have been to: 1) Estimate the biomass of spawning stocks of priority species of finfishes and shellfishes in the Gulf of Mexico, 2) determine the geographic distribution, time of spawning, and amount of spawning of eggs, larvae, and juveniles, and 3) study environmental factors affecting the abundance and distribution of eggs, larvae, and juveniles. These objectives have been supplemented from time to time with short-term specific objectives to conduct synoptic surveys, carry out intercalibration stations, describe distribution patterns of early life history stages, analyze zooplankton communities, analyze hydrographic conditions in relation to the distribution of organisms, cooperate with other institutions, and provide training and technology transfers.

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Methods

The major activity is to conduct large-scale ichthyoplankton surveys from both U.S. and Mexican research vessels. These surveys entail the use of a grid pattern of stations at a minimum distance of every 60 n.mi. or intersection of each degree of latitude and longitude. This grid pattern covers the waters of the Gulf of Mexico in the exclusive economic zones of the Unites States and Mexico and also includes the Caribbean coast of Mexico. The long-term intent is to sample each of these stations in each month of the year to provide eventually complete temporal and spatial coverage of the area. The principal sampling gear is the 60 cm bongo net using 0.333 mm mesh netting. The net is towed from 200 m depth or within 5 m of the bottom if less than 200 m to the surface with the vessel's speed maintaining a 45° wire angle as the net is retrieved at 20 m/second. Simultaneously a 10 minute surface tow is made with a neuston net. Ancillary data includes sea surface temperature, bathythermographs at each station, and, if possible, measurements of salinity, chlorophyll, Secchi disk, irradiance, nutrients, C_{14} updake, and Gelbstoff. These latter measurements were not required and were only collected intermittently. The resulting plankton samples are sorted by the respective agency supporting the cruise, or as in 1982, by the Plankton Sorting and Identification Center (Zaklad Sortowania I Oznaczania Planktonu) in Szczecin, Poland. Training and technology transfers include: The training of Mexican scientists at the NMFS Southeast Fisheries Center's Miami Labobory in identification, U.S. scientists have visited the Instituto Nacional de Pesca (INP) laboratory in Mexico City to identify larvae, Mexican scientists have served on the field parties of U.S. research vessels for training, U.S. scientists have furnished Mexican colleagues with literature pertinent to the discipline, and, finally, both U.S. and Mexican scientists have exchanged data and manuscripts.

Results

Table 1 summarizes the results of the ichthyoplankton surveys of the Gulf of Mexico since the formation of MEXUS-Gulf in 1977. In 1982 the first major cooperative survey took place and the participants are listed in Table 2. This extensive survey covered the entire area as shown in Figure 1. Preliminary results of that survey were jointly published by U.S. and Mexican scientists (Richards et al., 1984). Both Mexican and U.S. scientists have been interested in tunas and Figure 2 denotes the distribution of blackfin tuna larvae during 1982 as an example of the type of information generated by these surveys. Additionally, five reports have appeared which utilize data from this cooperative work. These include a description of the ecosystem by Sherman et al. (1983), a

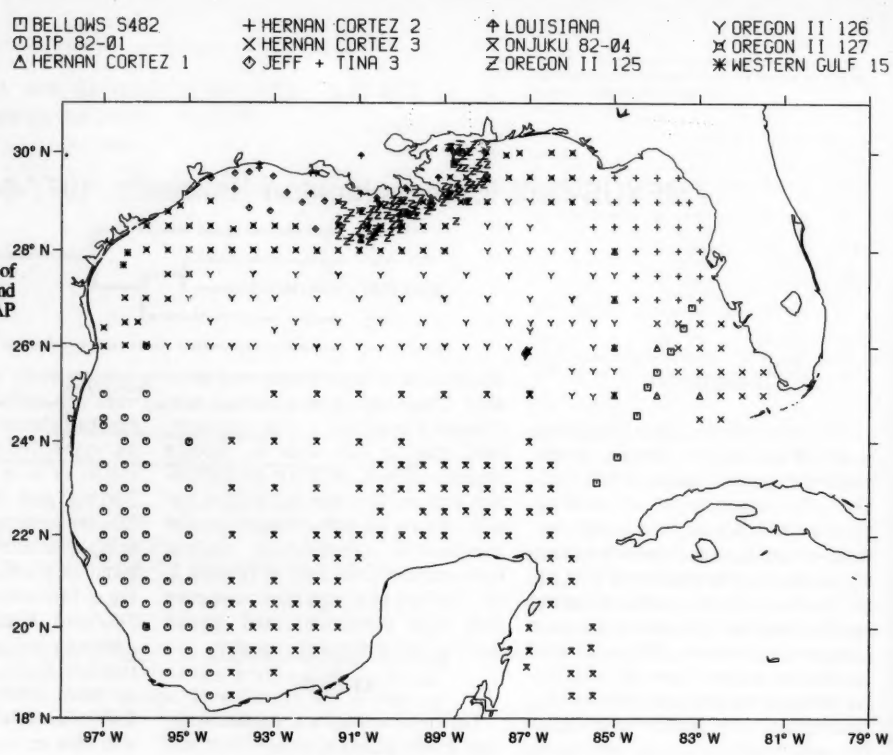

Figure 1.—Distribution of ichthyoplankton stations and vessels during SEAMAP 1982.

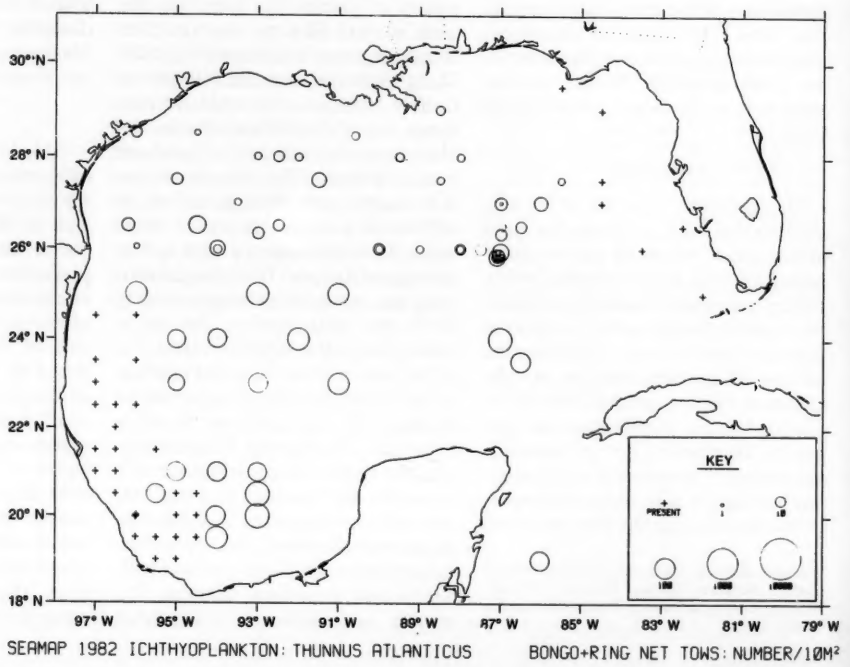

Figure 2.—Distribution and abundance of larvae of *Thunnus atlanticus* during SEAMAP 1982.

Table 1.—Summary of ichthyoplankton cruises and types of samples collected in the Gulf of Mexico 1977-1984.

Year	Cruise	Date	No. of completed stations	Environmental parameters										
				Bongo	Neuston	XBT	Surface temp.	Chloro-phyll	Salinity	Secchi disk	Irrad-iance	Nutri-ents	C_{14} uptake	Gelbs-toff
1977	*Oregon II*-77	April 29-May 24	48	X	X		X							
1978	*Oregon II*-87	May 2-May 30	134	X	X	X	X	X						
1980	*Oregon II*-105	Feb. 25-March 27	80	X	X	X	X	X			X	X	X	X
1981	*Oregon II*-117	May 1-May 26	102	X	X	X	X							
	Oregon II-120	August 15-August 28	45	X	X	X	X							
1982	*Oregon II*-126	April 15-May 23	120	X	X	X	X	X	X	X				
	SEAMAP	June-July	400	X	X	X	X	X	X					
1983	SEAMAP		—[1]	X	X	X	X	X	X					
1984	SEAMAP		—[1]	X	X	X	X	X	X					

[1]Incomplete data processing.

summary of research and bluefin tuna population estimates by Richards et al.,[1] a report on tuna larvae by Olvera (1984), a description of the results of the 1983 surveys by Kelley et al. (1986), and an analysis of the bluefin tuna larval results by McGowan and Richards (1986). This latter document formed the basis for a decision to index the bluefin stock in the Gulf of Mexico with larval data rather than a fishery.

The cooperative aspects of MEXUS-Gulf have yielded important information as already evidenced, and the continuance of this cooperative effort will yield outstanding results as the data are analyzed and as a long-term data base is generated. The Gulf of Mexico is one of the most dynamic ecosystems in the world and a continuing sampling program will yield important results. The long-term sampling will provide a long-term look at the dynamics of the system thus increasing the value of the data base each year as the data accumulate and refine the dynamic properties of the early life history stages of the fish and invertebrate communities.

Table 2.—SEAMAP 1982 participants.

Vessel	Cruise number	Station numbers	Gear	Dates 1982	Affiliation
Oregon II	126	36659-36787	Bongo, Neuston	4/15-5/25	NMFS
Bellows	S482	1-8	Neuston, Bongo	4/27-4/28	Fla. Dep. Nat. Resour.
Jeff & Tina	3	B213-B220	Bongo, Neuston	6/15-7/6	NMFS
Western Gulf	15	B233-B234	Bongo	6/23-6/24	Tex. Dep. Park Wildl.
Louisiana	0	1-43	Ring	6/1-7/30	La. Dep. Parks Wildl.
Oregon II	127	36788-37059	Bongo, Neuston	6/1-7/13	NMFS
Hernan Cortez	1	5-11	Neuston	5/16-5/20	Fla. Dep. Nat. Resour.
Hernan Cortez	2	A2-A30	Bongo, Neuston	6/9-6/13	Fla. Dep. Nat. Resour.
Hernan Cortez	3	31-49	Neuston, Bongo	6/20-6/22	Fla. Dep. Nat. Resour.
Oregon II	125	36005-36627	Bongo	2/24-3/17	NMFS
Onjuku	82	65-13050	Bongo		INP
BIP	82-01	11040-13050	Bongo		INP
Onjuku	82-04	50110-15011	Bongo	6/1-7/23	INP
BIP	82-01	70-30-80-30	Bongo	5/1-6/21	INP
Onjuku	82-04	14090-16023	Bondo	5/1-6/30	INP

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Richards, W. J., T. Potthoff, S. Kelley, M. F. McGowan, L. Ejsymont, J. H. Power, and R. M. Olvera L. 1984. SEAMAP 1982 - Ichthyoplankton larval distribution and abundance of Engraulidae, Carangidae, Clupeidae, Lutjanidae, Serranidae, Coryphaenidae, Istiophoridae, Xiphiidae and Scombridae in the Gulf of Mexico. NOAA Tech. Memo. NMFS-SEFC-144, 50 p.

Sherman, K., R. Lasker, W. Richards, and A. W. Kendall, Jr. 1983. Ichthyoplankton and fish recruitment studies in large marine ecosystems. Mar. Fish. Rev. 45(10-12):1-25.

[1]Richards, W. J., M. F. McGowan, and J. A. Ortner. 1983. Summary of Gulf of Mexico ichthyoplankton research 1977-1982 with bluefin tuna population estimates and preliminary analyses of larval bluefin distribution and ichthyoplankton assemblages. Miami Lab., NMFS Southeast Fish. Cent., Miami, Fla., 22 p. manuscr.

MEXUS-Gulf Remote Sensing and Technology Research 1977-84

ANDREW J. KEMMERER, THOMAS D. LEMING, and WALTER F. GANDY

Introduction

The Remote Sensing Working Group of MEXUS-Gulf was organized because of an interest in remote sensing shared by the fisheries organizations of Mexico and the United States. This interest was due to an appreciation by both nations of the contributions that remote sensing could make to increased understandings of the fisheries and ecology of the Gulf of Mexico.

Numerous efforts were made beginning in 1979 to initiate a cooperative remote sensing study from which both countries could benefit. Mexico's interest, however, initially was focused on hydroacoustics and interest in the United States was directed primarily at aerospace forms of remote sensing. Unfortunately, neither country had the capability to initiate a meaningful exchange of information related to the Gulf of Mexico in the initial phases of MEXUS-Gulf.

In 1981, an advanced state-of-the-art digital image processor was installed within the Mississippi Laboratories of the Southeast Fisheries Center (SEFC) of the National Marine Fisheries Service (NMFS), and work began in Mexico by the Instituto Nacional de Pesca (INP), Departmento de Pesca, to apply high resolution acoustics to problems related to plankton assessment. These remote sensing technologies may provide a basis from which cooperative efforts and exchanges now can spring to further the goals of MEXUS-Gulf.

The Technology Working Group of MEXUS-Gulf was one of the later working groups formed and has not had sufficient time to fully develop mechanisms for effective exchanges of information or cooperative research programs. In 1981, the Remote Sensing and Technology Working Groups combined efforts to initiate meaningful research in 1982. Plans were developed for information exchanges primarily related to fishing and fuel efficiencies in commercial shrimp fleets.

This paper summarizes initial efforts directly or indirectly stimulated by MEXUS-Gulf in remote sensing and technology. These efforts fall into three general areas: Radio and satellite tracking of sea turtles, fuel efficiencies in shrimp fisheries, and analyses of satellite imagery for derived chlorophyll patterns and concentrations. This paper provides a basis for more comprehensive summaries jointly authored by investigators from Mexico and the United States.

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Radio and Satellite Tracking

Radio Tracking

Radio tracking of sea turtles by NMFS was done to judge the success or failure of the initial phase of releases of headstarted Kemp ridley turtles, *Lepidochelys kempi*. The headstarting was initiated jointly by Mexico and the United States in 1978 when turtle eggs were collected from nesting grounds near Ranch Nuevo, Tamaulipas, Mexico, for rearing at the SEFC Galveston Laboratory in Texas. The first few months after release were considered especially critical for the turtles, and it was this period which formulated the basis for radio tracking. Subsequently, however, radio tracking capabilities were expanded to include more than just headstarted sea turtles.

Steps to develop a radio tracking capability included a series of controlled experiments to optimize attachment procedures and to evaluate effects on turtle behavior. No significant effects were noted in surfacing or feeding behavior when the transmitters were trailed behind the animals on lanyards roughly-two-thirds the carapace length. The transmitters (8 g) were enclosed in triangular wooden pyramidal floats with a total air weight of 28 g. The advantage of the lanyard attachment method was that it allowed full exposure of the transmitter antenna every time the turtle surfaced. The radiated power of the transmitter in saltwater averaged −7 dbm with a capability of 45 days of continuous operation (Timko and De Blanc, 1981).

The turtles were tracked by an aircraft equipped with a high-gain (130 db) battery powered receiver. The receiver could be manually tuned to differentiate and receive signals from up to 100 different turtles. Three-element yagi antennas were mounted on the wings and a dipole quarter-wave antenna was installed on the underside of the aircraft. The yagi antennas provided directional capability for tracking and the dipole was used for initial detection. Detection range was about 50 km. A Loran-C navigation system was used to help position the turtles.

Three demonstrations of the tracking system were conducted before it was considered operational. All three were conducted in the eastern Gulf of Mexico. The first demonstration was relatively unsuccessful due to fatigue or corrosion of stainless steel lanyards used to attach the transmitters to an initial group of ten headstarted ridley turtles. The stainless steel lanyards were replaced with nylon monofilament for the subsequent demonstrations which were successful. Selected turtles were tracked for periods of up to 30 days following

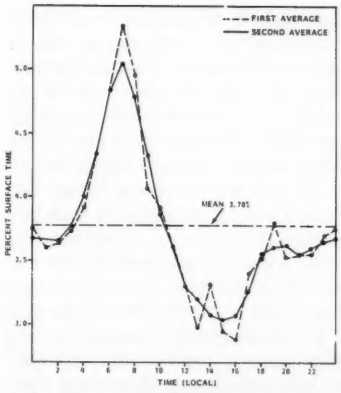

Figure 1.—Time averaged diurnal surfacing pattern (percent surface time) of loggerhead sea turtles. Averaging done by combining data from adjoining hours of an hour with data from that hour. Second average done similar to first, but with average values from the first averaging. After Kemmerer et al., text footnote 1.

release, with some of them traveling as far as 240 km offshore.

A cooperative demonstration of the radio tracking system was completed by representatives of INP and SEFC in 1981. Transmitters and a receiver were provided for a tracking experiment off Mexico.

The radio tracking capability was expanded in 1981 to monitor movements and surfacing behavior of adult loggerhead sea turtles, *Caretta caretta*, near the Canaveral Channel, Florida (Kemmerer et al.[1]). The same tracking and attachment rationale used for the headstarted turtles was used with the addition of shore-based spectrum analyzer to continuously monitor absence or presence of radio signals. Data from 20 days of continuous monitoring of 20 radio-equipped turtles suggested that about 3 days were needed for the animals to normalize surfacing behavior patterns (i.e., adjust to capture, handling, and tagging). The mean time spent by a turtle during a surfacing was 2.20 minutes, and the turtles averaged 1.03 surfacings an hour. The turtles spent an average of 3.78 percent of their time at the surface and a trend analysis indicated diurnal periodicity in surfacing behavior (Fig. 1).

[1]Kemmerer, A. J., R. E. Timko, and S. B. Burkett. Movement and surfacing behavior patterns of loggerhead sea turtles in and near Cape Canaveral Channel, Florida (September and October 1981). Manuscr. on file at National Marine Fisheries Service, Southeast Fisheries Center, Mississippi Laboratories, NSTL Station, Miss.

Satellite Tracking

Long-term tracking studies of far-ranging sea turtles were considered to be practically impossible with traditional radio tracking techniques primarily because of cost constraints. These constraints led SEFC investigators to consider the use of satellite systems whose feasibility had already been demonstrated for tracking elk (Craighead et al., 1972) and polar bears (Kolz et al., 1980).

Transmitters originally developed to track polar bears were modified for use with sea turtles (Timko and Kolz, 1982). The transmitters were designed to operate through the Nimbus-6 satellite which carries a data collection and transmitter location system capable of handling random transmissions from up to 1,000 transmitters worldwide. Data are transmitted to the satellite as 401.2 MHz radio frequency pulses. The pulses have a duration of about 1 second and occur at a rate of about one per minute. Each pulse contains an unmodulated carrier and a phase-modulated section for data synchronization and transmitter identification. The unmodulated portion of the carrier is used to measure the doppler frequency shift and to calculate the latitude and longitude of the transmitter. Location accuracy is about $\pm$ 5 km.

The transmitter was designed to operate for 1 year with a duty cycle of an 8 hour transmission period every 4 days to conserve battery power. It was completely enclosed in 16 cm diameter PVC pipe 28 cm in length. The transmitter package weighed about 3.2 kg in air and floated 40 percent exposed or 1.8 kg positively buoyant. A secondary radio beacon also was included in the PVC pipe to continuously radiate 165 MHz radio frequency pulses. The secondary beacon was added to allow the turtle to be located by search aircraft. A complete description of the transmitter is given by Timko and Kolz (1982).

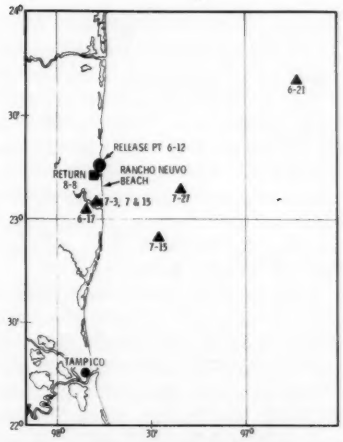

Figure 2.—Satellite derived positions for cooperative MEXUS-Gulf Kemp ridley sea turtle tracking equipment (1980).

After a series of captive animal tests, the first field demonstration of a satellite tracking capability for sea turtles was conducted. A 96 kg female loggerhead turtle, nicknamed "Dianne", was outfitted with a Nimbus-6 transmitter and released off the coast of Mississippi in October 1979. The transmitter was attached to the trailing edge of the turtle's carapace with a lanyard about two-thirds the length of the carapace. Dianne was successfully tracked for 8 months over a distance exceeding 2,200 km (Timko and Kolz, 1982).

The success of the satellite tracking demonstration prompted a cooperative effort between INP and SEFC investigators to track a Kemp ridley turtle. In June 1980, a 67.3 cm carapace length female ridley was tagged with a Nimbus-6 transmitter at Rancho Nuevo, Mexico. The transmitter was attached after the turtle deposited her clutch of eggs. She was allowed to return naturally to the sea and to swim through the surf.

The first returns from the satellite indicated the ridley turtle had moved a short distance off the nesting beach (Fig. 2), but later returns from a position roughly 25 km south of the release site in Barre del Tordos, an inland lagoon,

indicated a detachment problem. After an extensive search, the transmitter was located in a fishing camp being used as a float on a gill net. No evidence of what had happened to the female ridley was found, although it was generally assumed she had been caught by a fisherman. The conclusion from the experiment was the transmitter probably was too large for the ridley turtle and may have led to her capture.

Partly because of the presumed failure with tracking the Kemp ridley, but primarily because of a phasing down of the Nimbus-6 system by the National Aeronautics and Space Administration (NASA), engineering research and development shifted to a new satellite—TIROS-N. This satellite carries a data collection and platform location system similar to the one aboard Nimbus-6 but with expanded capabilities. The system, referred to as ARGOS, represents a cooperative effort by the United States and France, with France providing the hardware and data processing and the United States providing the space vehicles and support systems. ARGOS is proposed to be operational on all NOAA series satellites.

The ARGOS data collection and platform locationing system is capable of providing precise location and data retrieval from fixed or mobile transmitter platforms worldwide. The platforms transmit a coded message at 401.65 MHz which includes an unique identification code, sensor data, and an unmodulated carrier. The unmodulated carrier is used to calculate platform positions which tests by NMFS engineers indicate can be as accurate as 21 m. Message duration depends on the quantity of data to be transmitted, but is always less than 1 second.

Major advantages of the ARGOS system are that it has two satellites in orbit, compared to the single Nimbus-6 system, and its planned long-term operational capability. All transmitters must provide a minimum of 7 uplinks to be located. These uplinks, however, can be with one or both satellites which overall should increase the probability of tracking briefly surfacing marine animals.

Two prototype ARGOS sea turtle transmitters were recently developed by NMFS. The transmitters are similar in design to the ones used for tracking the loggerhead and Kemp ridley turtles. A major advantage of these transmitters is their greatly reduced size, which is roughly 22 percent displacement volume, 41 percent air weight, and 13 percent buoyancy of the Nimbus-6 transmitters (Table 1). While they are probably still too large for tracking most juvenile turtles, they appear to have significant potential for tracking all adult sizes of the five sea turtle species endemic to the Gulf of Mexico.

Table 1.—Comparison of Nimbus-6 and ARGOS sea turtle tracking transmitters.

Parameter	Nimbus-6	ARGOS
Air Weight (kg)	3.2	1.3
Buoyancy (kg)	1.8	0.23
Length (cm)	28	50.8
Diameter (cm)	16	5.1
Displacement volume (cm^3)	5,444	1,207

The turtle transmitters have been certified by ARGOS and a semicontrolled captive animal test was completed with one of the transmitters attached to a loggerhead turtle. The transmitter operated perfectly even though the turtle escaped from captivity after several weeks, and the transmitter had to be used for location and recovery. The first wild animal test was planned to begin in September 1982 with release of a transmitter tagged adult loggerhead turtle in the northcentral Gulf of Mexico.

Technology

Technology efforts in the United States related to MEXUS-Gulf have concentrated on characterizations of fishing and gear efficiencies in the Gulf of Mexico shrimp fleet. Scientific observers aboard cooperating offshore shrimp trawlers have recorded information on time and fuel budgets since 1980. Twenty vessels in the Gulf were monitored for time budgets covering 119 trips ranging in length from 6 hours to 17 days. An additional three monitored vessels ranging in length from 19.2 to 25.9 m and powered with diesel engines from 275 to 520 mhp were equipped with microprocessor fuel flow and tachometer systems.

Most significant of the findings from the observer monitoring is that while the vessels spent only slightly more than 50 percent of the time fishing, this activity consumed almost 70 percent of the fuel. Running time to and from fishing grounds and between fishing grounds accounted for 19 percent of the time and 28 percent of the fuel budgets, respectively. Roughly 25 percent of the time budget was used without the main propulsion unit operating. Very little time, about 1 percent, was spent fishing with try-nets alone and accounted for less than 1 percent of the fuel consumed. Gear handling also accounted for very small portions of the time and fuel budgets representing about 1 and 2 percent of the two budgets, respectively. A comprehensive review of findings from this study is given by Veal et al.[2]

Review of shrimp trawls indicated that since 1970 there have been numerous changes, but most of the changes have remained with the basic balloon, semiballoon, and flat trawl design. The two most recent changes have been with development of the twin and tongue trawls. The development of the twin trawl, however, is more a development in rigging than in trawl design. The twin trawl essentially consists of two smaller trawls tied together with an extra door, sled, or bullet between the nets. The primary advantage of the twin trawl is an increase in horizontal spread without an accompanying increase in drag. The development of the tongue trawl was an attempt to combine advantages of twin and single trawls into a single net. The distinguishing feature of the tongue trawl is a section of webbing that extends forward from the top of the net and connects to a central and extra trawl bridle. The rationale of the design was to increase horizontal spread of the net by reducing total load on the doors. This was done by transferring a portion of the load to the tongue and central bridle.

A series of underway measurements on a selected group of shrimp trawls was made by SEFC scuba divers to evaluate spread efficiencies (Table 2). Each trawl

[2]Veal, D. D., M. V. Rawson, and W. Hosking. 1981. Structure, strategy and fuel consumption in the Gulf shrimp fleet. Paper presented at Fishing Industry Energy Conservation Conference, Soc. Naval Archit. Mar. Engr., Seattle, Wash., Oct. 26-27, 1981.

was 18.3 m headrope length (webbing to webbing) and was constructed by a commercial trawl manufacturer. The trawls were rigged identically with standard loop chains and without floatation. Chain wooden doors 2.4 by 1.0 m were used to spread the nets and the trawls towed in 9 m of water using 15.2 m bridles and 22.9 m warps.

The tongue trawls outperformed the other trawls in spread efficiency, ranging from 80 to 85 percent. Efficiency is the horizontal spread of the net expressed as a percentage of headrope length. Based on these measurements, the tongue trawls appear best suited for the bottom dwelling brown shrimp, *Penaeus aztecus*, and pink shrimp, *P. duorarum*. The Mongoose trawl may be the best overall tongue-type of trawl because of its greater vertical opening and relatively good spread efficiency, although less than the other two tongue trawls. The greater vertical opening would be especially important for white shrimp, *P. setiferus*, and at times for the other two species when for reasons related to currents or behavior they are off the bottom. A comprehensive review of these measurements together with measurements from other nets with and without tongues, with and without floats, and with different door sizes is given by Watson et al.[3]

A series of instrumented tows of a Mongoose trawl were made to judge performance characteristics under simulated fishing conditions. Preliminary measurements indicated that during a relatively long trawl tow, vessel speed through the water and engine rpm would decrease with an accompanying increase in the rate of fuel consumption even though throttle settings were fixed. Additionally, the horizontal spread of the net decreased, all presumably due to increased net loadings. In one series of measurements, the swept area efficiency of the net was found to decrease 40 percent over a 150-minute tow which together with a 4 percent increase in the rate of fuel consumption suggested the tow was 44 percent less efficient when the last measurements were made than when the trawl was first put over the side of the trawler (Kemmerer et al.[4]).

In another series of instrumented trawl tows, several types of nets were evaluated for swept area fishing efficiency as a function of fuel consumption. The twin trawl was found to be 38 percent more efficient than were any of the single trawls tested at vessel speeds through the water comparable to commercial fishing operations (Kemmerer et al.[4]). A 50 percent increase in area swept by the twin trawl, which was provided by increasing towing speed, required roughly a 400 percent increase in fuel consumption. Increases of 40 percent in area swept by single trawls similarly required nearly 400 percent increases in rates of fuel consumption.

Table 2.—Comparisons between eight common shrimp trawls. Measurements were made while being towed 1.3-1.5 m/seconds. Headropes were all 18.3 m (after Watson et al., text footnote 3).

Trawl	Spread (m)	Vertical opening (m)	Spread efficiency (%)
Flat	12.2	1.2	67
Semiballoon	12.2	1.2	67
Western jib[1]	12.5	1.1	68
Balloon	12.8	1.1	70
Super X-3[2]	13.4	1.1	73
Super X-3 tongue	15.5	0.6	85
Cobra/hood tongue[3]	14.9	0.8	82
Mongoose tongue[4]	14.6	1.2	80

[1]Similar to flat trawl with major difference in construction of the corner pieces.
[2]Similar to western jib, but with differences in the corner pieces.
[3]Similar to semiballoon trawl with addition of a tongue added to the top body panel.
[4]Similar to Cobra trawl with major difference being the tongue is designed into the trawl.

Satellite Remote Sensing

Availability of the SEFC satellite image processor and discussions with INP investigators in 1981 prompted efforts to process selected images provided by the Coastal Zone Color Scanner (CZCS). This particular remote sensing system was stressed because it is the only color sensor in orbit specifically designed for application to the oceans of the world. Rather than attempting to process all available CZCS data available for the Gulf of Mexico, an area off the coast of Mexico which experienced several periods of significant meteorological perturbations in 1979 was examined for a time series of chlorophyll patterns and concentrations (Fig. 3).

Satellite System

The CZCS system is carried by Nimbus-7 which was launched in October 1978. The spacecraft is a research platform of the NASA Goddard Space Flight Center with a threefold monitoring mission: Atmospheric pollution, oceanography, and atmospheric sciences. Two instruments are dedicated to oceanography, the CZCS and a scanning microwave radiometer. The spacecraft is in a sun-synchronous, near-polar (99.28°), 955 km altitude orbit with an ascending-node equator crossing near local noon (Hovis et al., 1980). Repeat coverage at the equator is every 3 days with at least daily coverage about 60°N.

The CZCS has four high resolution (20 nm) spectral bands in the visible spectral region and two in the nonvisible region. Center wavelengths are 443, 520, 550, 670, 750, and 11,500 nm. The spectral characteristics of the CZCS were governed by the spectra of phytoplankton (Morel and Prieur, 1977) while the radiometric sensitivity of the sensor was determined by the magnitude of expected radiances from the sea surface (Gordon et al., 1980). Bands 1 and 4 of the sensor (centered at 443 and 670 nm, respectively) span spectral regions of strong chlorophyll-*a* absorption. Band 3, centered at 550 nm, falls in a region of minimum chlorophyll-*a* absorption while Band 2, center at 520 nm, is near a point where subsurface upwelling radiance is nearly independent of the concentration of chlorophyll-*a* (Gordon et al., 1980). Band 5 (700 to 800 nm) is used primarily for discriminating between land, clouds, and water, and Band 6 (10,500 to 12,500 nm) is a thermal infrared detector for monitoring sea-surface temperature. All 6 bands are perfectly coregistered.

The CZCS has an active scan of 78° centered on nadir and a ground resolution of 825 nm. A normal complete

[3]Watson, J. W., I. K. Workman, D. W. Taylor, and A. F. Serra. Configurations of common shrimp trawls employed in southeastern United States waters. Manuscr. on file at National Marine Fisheries Service, Southeast Fisheries Center, Mississippi Laboratories, Pascagoula, Miss.

[4]Kemmerer, A. J., W. R. Seidel, C. D Veal, and W. Hosking. 1982. Fuel relationships in southeastern United States shrimp fisheries. Rep. to Int. Counc. Explor. Sea, Copenhagen.

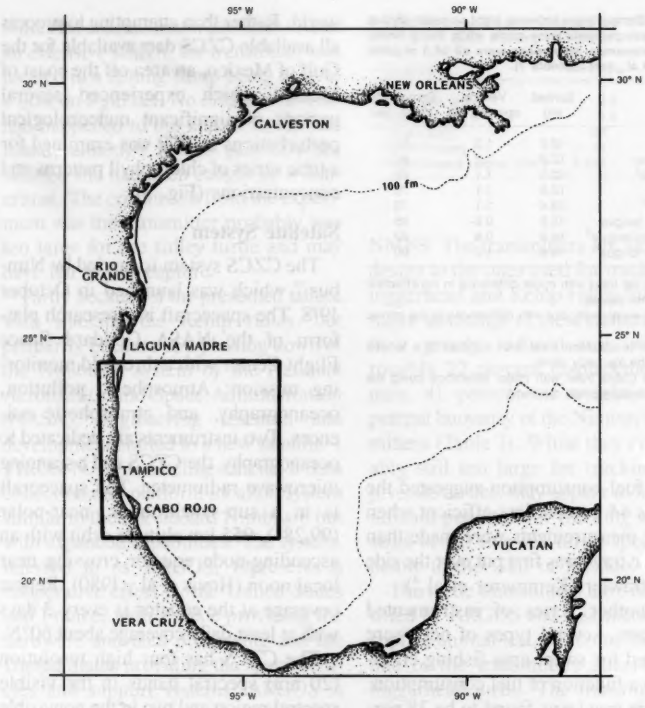

Figure 3.—Study area showing approximate CZCS coverage area (outlined rectangle) for Figure 4A-D.

scene requires about 2 minutes to acquire and is about 800 km along the satellite track and 1,600 km across track. The scan plane of the sensor can be tilted ±20° from nadir along track to minimize sunglint.

Algorithms

Before CZCS imagery is used to compute chlorophyll concentrations, the digital data must be corrected for atmospheric scattering by air molecules and aerosols. Typically, the desired water-leaving radiance is only 10-20 percent of that actually measured at satellite altitude with the majority of the radiance due to atmospheric scattering (Gordon and Clark, 1981). Several techniques are available for the correction and the one used is based on the concept of clear-water radiance (described by Gordon and Clark, 1981). The advantage of this technique is it does not require surface truth information.

Essentially, the clear water radiance correction technique is based on a demonstrated capability to compute radiances at 520, 550, and 670 nm for very clear oceanic waters (i.e., chlorophyll concentrations less than 0.25 mg/m^3), knowing only the solar zenith angle (Gordon and Clark, 1981). As Rayleigh scattering can be computed from theory with information on spacecraft-pixel geometry and solar elevation and azimuth, the scattering from aerosols can be inferred directly from spacecraft radiance measurements given certain assumptions are satisfied (Gordon and Clark, 1981). Water radiances can then be extracted from the data and are assumed to represent absolute intensities from just below the sea surface.

The majority of CZCS chlorophyll algorithms are based on linear regression models where the logarithm of chlorophyll concentration is computed from a logarithm of the ratio of radiances from two CZCS bands. Smith and Baker (1982) review a number of these regression algorithms, noting that r^2 values from four separate studies were all above 0.90 for cholorphyll concentrations ranging from 0.01 to 10 mg/m^3.

Chlorophyll concentrations presented in this paper were inferred from atmospherically corrected CZCS radiances applied to a chlorophyll algorithm currently used by NASA to process CZCS data to the derived product stage. The algorithm is in two equations where the logarithm of chlorophyll concentrations less than 1.5 mg/m^3 is estimated from a ratio of CZCS radiances from bands centered at 443 and 550 nm, and concentrations between 1.5 and 32 mg/m^3 are estimated from a ratio of radiances from bands centered at 520 and 550 nm. The expected accuracy of the estimate is 0.25-0.50 the logarithm of the chlorophyll concentration (Gordon and Clark, 1980).

Derived Chlorophyll

Chlorophyll charts derived from four CZCS coverages of the study area off Mexico are presented in Figure 4. Figure 4A shows chlorophyll concentrations from 21 August 1979. Coastal concentrations averaged about 0.50 mg/m^3, and for the complete scene, less land and cloud pixels, the arithmetic mean concentration was 0.18 mg/m^3. A frequency analysis of the scene with cumulative percent curves for area and chlorophyll concentration is presented in Figure 5A. This scene is assumed to represent normal conditions for the area with the highest chlorophyll concentrations immediately adjacent to the coast.

Coverage by the CZCS about a month after the first image on 29 September 1979 showed a major phytoplankton bloom had or was occurring (Fig. 4B). The bloom was generally confined to an area from the coast out to a depth of about 180 m. Chlorophyll concentrations in the region of the bloom averaged about 2.5 mg/m^3 which increased the mean for the entire scene to 0.66 mg/m^3. This increase represents roughly a 266 percent increase in the amount of chlorophyll from the first to the second CZCS scene. The frequency analysis for the scene (Fig. 5B) shows two

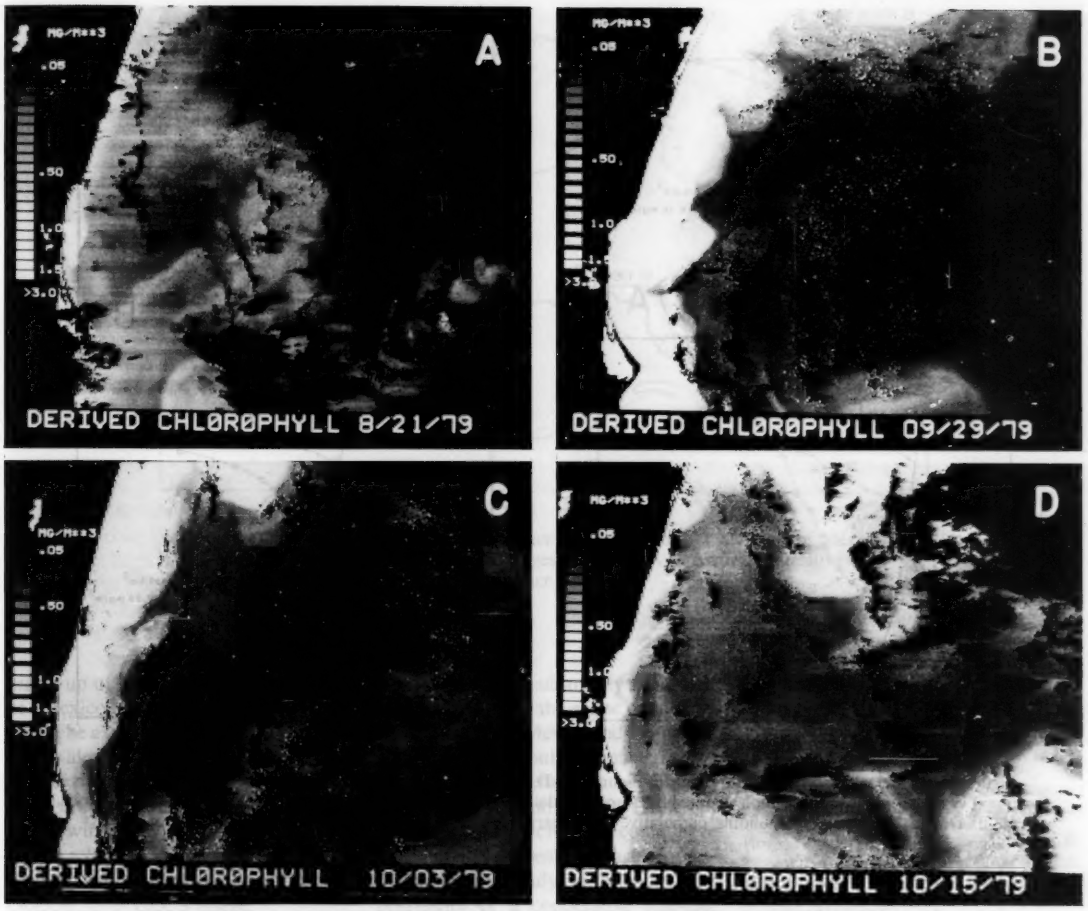

Figure 4.—Chlorophyll charts derived from CZCS digital data. The images consist of 512 × 512 picture elements (pixels), each representing a surface area of about 825 × 825 m. Chlorophyll concentrations in mg/m^3 are depicted according to the gray scale. Black areas are land or clouds: A, 21 August 1979; B, 29 September 1979; C, 3 October 1979; and D, 15 October 1979.

peaks in chlorophyll concentration. The first peak at about 0.14 mg/m^3 is characteristic of chlorophyll concentrations in clear oceanic waters while the second at about 2.5 mg/m^3 defines concentrations associated with the bloom.

By 3 October 1979 the intensity of the chlorophyll bloom had subsided (Fig. 4C). Concentrations along the coast were still high, but had fallen to an average of about 1.0 mg/m^3. The mean for the scene was 0.30 mg/m^3. The area frequency analysis for the scene indicated a peak in chlorophyll concentration at about 0.18 mg/m^3, with two smaller peaks at 0.80 and 1.58 mg/m^3 (Fig. 5C). Sensor coverage almost two weeks later showed chlorophyll concentrations along the coast had fallen back to levels roughly the same as before the bloom (Fig. 4D). Significant concentrations of oceanic chlorophyll, however, were apparent in the northcentral and southeastern portions of the image which resulted in a leveling out of the mean chlorophyll concentration at 0.29 mg/m^3. The area frequency analysis showed the major chlorophyll concentration peak at about 0.19 mg/m^3 with a secondary substantial peak at 0.40 mg/m^3 (Fig. 5D).

Discussion of the Chlorophyll Bloom

A completely satisfactory explanation for the chlorophyll bloom sensed by the CZCS on 29 September 1979 is not possible due to the lack of accompanying surface truth information. However, a plausible explanation is available from meteorological data provided by the National Climatic Clenter of the National

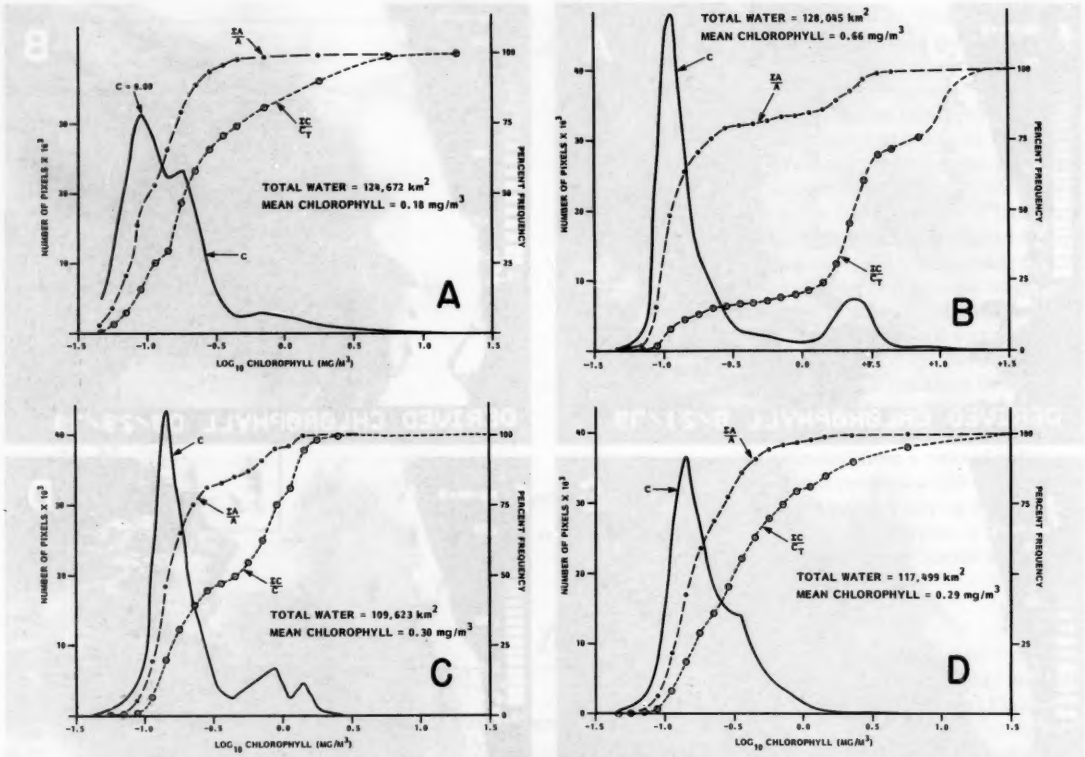

Figure 5.—Statistical analysis of water pixels of Figures 4A-D. Solid lines are frequency distributions of number of pixels (area) vs. chlorophyll concentration. Dashed lines are cumulative chlorophyll distributions as a percentage of total chlorophyll. Dotted lines are corresponding cumulative area distributions as a percentage of total water area.

Oceanic and Atmospheric Administration. These data show that the western Gulf of Mexico experienced severe changes in meteorological conditions during the CZCS coverage period (Fig. 6).

On 21 August 1979, the date of the first CZCS coverage, surface winds were light and easterly or southeasterly in the southwestern Gulf of Mexico (Fig. 6A). From 10 to 15 September 1979, wind circulation in the entire Gulf was dominated by Hurricane Frederick (Fig. 6B) which passed through the central Gulf and made landfall near Pascagoula, Miss. Hurricane Henri was spawned in the southwestern Gulf on 17 September 1979, and on 18 September 1979 was only about 200 km east-southeast of Cabo Rojo (Fig. 6C). Winds along the coast north of Cabo Rojo were northeasterly at about 20.5 m/second (40 knots) while maximum winds near the eye of the hurricane were near 38.6 m/second (75 knots). While these wind directions are not favorable for coastal upwelling, their magnitude coupled with the low atmospheric pressures associated with Hurricane Henri could cause extreme vertical mixing bringing cooler water and nutrients into the surface layers. Presumably, it was this vertical mixing which led to the chlorophyll bloom sensed by the CZCS on 29 September 1979. Hurricane Henri was downgraded to a Tropical Depression on 19 September 1979, and remained in the southwest Gulf for nearly 3 days before drifting to the northeast and dissipating on 24 September 1979.

By 29 September 1979, the date of the chlorophyll bloom sensed by CZCS, all traces of Hurricane Henri had vanished and winds were generally light and northerly along the east coast of Mexico (Fig. 6D). These winds would not have been conducive to coastal upwelling. Offshore winds near Yucatan were also light, but could have tended to drive surface waters toward the north. On 3 October 1979, surface winds were still light and variable, but generally northerly in the southwestern Gulf (Fig. 6E). Winds in this direction could have led to downwelling along the coasts of Mexico and Yucatan. Between 3 and 15 October 1979, the winds turned to northeasterly and intensified to between 5.1 and 12.9 m/second (10-25 knots). Wind driven transport would have caused a

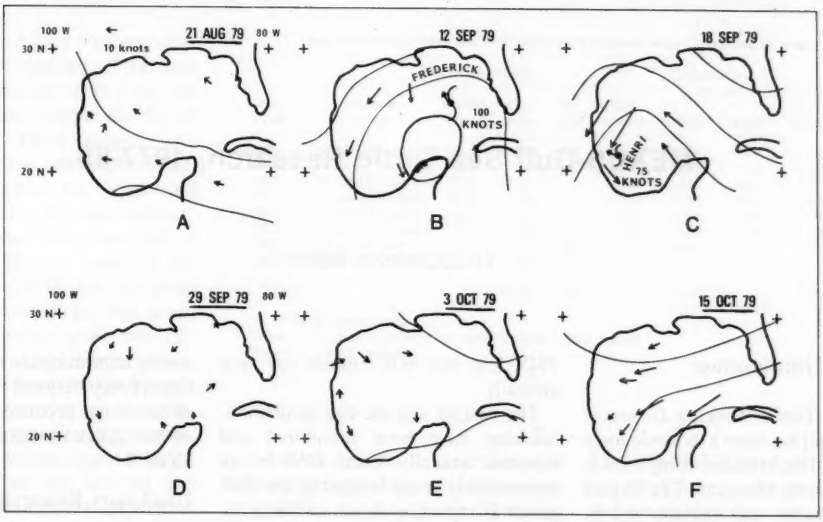

Figure 6.—Selected meteorological surface analysis charts for the Gulf of Mexico. Underlined dates are those for CZCS images in Figure 4A-D. Arrows are relative wind velocity vectors and solid lines are surface isobars.

piling up of water along the east coast of Mexico and strong downwelling would be expected (Fig. 6F). The same winds also would be expected to drive surface waters away from the Yucatan coast toward the central Western Gulf. These winds may have been the reason for the relatively chlorophyll-rich waters in the southeastern corner of the 15 October 1979 CZCS image.

Conclusions and Recommendations

The Remote Sensing and Technology Working Groups of MEXUS-Gulf have been relatively inactive since the inception of MEXUS-Gulf. Even with a low level of activity, however, significant progress has been achieved primarily in areas related to animal tracking and satellite remote sensing. The progress in these areas suggest the working groups should concentrate more of their efforts in these two areas to develop associations which ultimately could lead to a broadening in the scope of cooperative research by Mexico and the United States. Efforts should be intensified to train Mexican scientists in satellite image processing and then to seek out means so these scientists could have time available to them on image processing systems already in Mexico. The possibility of a cooperative tracking study of a Kemp ridley sea turtle with the newly developed ARGOS transmitters also should be explored.

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MEXUS-Gulf Sea Turtle Research, 1977-85

FREDERICK H. BERRY

Introduction

The Sea Turtle Working Group of MEXUS-Gulf has been a dynamic force since 1977. The Mexican delegation is headed by Rene Marquez. The United States delegation was initially led by Peter Pritchard and later by F. H. Berry. Several organizations have collaborated in these efforts in addition to the Southeast Fisheries Center of the National Marine Fisheries Service (NMFS) and the Instituto Nacional de Pesca (INP), notably the U.S. Fish and Wildlife Service and the U.S. National Park Service on Kemp's ridley and the Intergovernmental Oceanographic Commission Association for the Caribean and Adjacent Regions for WATS. This research summary is reported in three sections: Kemp's ridley, *Lepiodochelys kempii*; TED (Turtle Excluder Device); and WATS (Western Atlantic Turtle Symposium).

Kemp's Ridley Research

The Kemp's ridley sea turtle is reduced to a single nesting population along the beach around Rancho Nuevo, Tamaulipas, Mexico. The subadults and nonnesting adults forage along the eastern coasts of Mexico and the United States and intrude into the eastern Atlantic, with an estimated two-thirds of this population in U.S. waters. This is considered the most endangered of the seven species of sea turtles. From an estimated 70,000 nesting females in 1947, less than 600 females now nest annually.

The nesting and the egg incubation-hatching have been monitored and reported annually since 1968 by an international group headed by the INP, which is reporting those activities.

The Kemp's Ridley Research and Management Plan developed by NMFS in 1984 would have added significantly to knowledge of Kemp's ridley problems by surveying for the first time the species in the water off the nesting beach during the nesting season and by short and long-term tracking of these animals. However, the plans have been cancelled the past 2 years for administrative reasons.

Incubation and "Imprinting" Research

Yearly, since 1978, about 20 clutches of Kemp's ridley sea turtle eggs have been collected from the nesting beach at Rancho Nuevo, Mexico, packed separately in styrofoam boxes containing Padre Island sand, flown to Padre Island National Seashore, incubated, hatched, and hypothetically imprinted to Padre Island. Afterward, the hatchlings have been transported to the NMFS Galveston Laboratory, in Texas to participate in the Head-start Project.

This program has produced an 8-year hatching success of 76.5 percent for the 17,447 eggs incubated at Padre Island (Table 1). This success has resulted in the contribution of 11,893 hatchlings to the Head-start Project. Yearly hatching success has consistently remained above 75 percent (Table 1) except for the 1983 year-class whose catastrophic failure was the result of fungal infection. Hatchlings death and hatchling escape during imprinting are responsible for the discrepancy between the yearly number of hatchlings produced and the number of hatchlings transported to NMFS in Table 1.

Head-start Research

Hatchlings received at the Galveston Laboratory are reared in captivity for 10-11 months. Healthy survivors in good condition are tagged and released into the Gulf of Mexico with the hypothesis that some will survive and instinctively return to their natal beach (either Padre Island or Rancho Nuevo) to nest as adults. Through 1985, 9,258 Kemp's ridleys representing the 1978-84 year-classes have been reared, tagged, and released into the Gulf of Mexico. Another 249 have been distributed to other facilities for extended head-starting and captive breeding, and an additional 15 of the 1984 year-class are being held for transfer to Cayman Turtle Farm Ltd., Grand Cayman, British West Indies.

Prior to release, all head-start turtles are tagged with an individually numbered metal flipper tag. Most of the tagged turtles have been released off the

Table 1.—Total number of eggs, hatching success, and the number of hatchlings contributed to the NMFS Head-start Project from Padre Island National Seashore for each year from 1978 through 1985.

Year	Total number of eggs	Percent of eggs hatched	No. of hatchlings to NMFS
1978	2,191	88.1	1,829
1979	2,053	86.2	1,661
1980	2,976	84.1	1,614
1981	2,279	83.3	1,868
1982	2,017	77.6	1,524
1983	2,006	12.1	230
1984	1,976	90.7	1,544
1985	1,978	84.1	1,623
Total	17,476	76.5	11,893

Frederick H. Berry, recently retired from the Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149, is currently Secretary to the Second Western Atlantic Turtle Symposium (WATS II), 6450 S.W. 81 St., Miami, FL 33143.

coast of the Padre Island National Seashore. Some were released off the west coast and southern tip of Florida, the upper coast of Texas, and in the Bay of Campeche. Of those tagged and released, 394 have been recovered. About 65 percent have been recovered alive and returned to the environment. Recoveries reported from the Gulf of Mexico, from the east coast of the United States, and from the European Atlantic coast demonstrate that head-started turtles survive, grow, and migrate in the wild. On a limited basis, radio tracking of head-started Kemp's ridleys has been tested using transmitters attached to the yearling turtles. These studies show that tagged released turtles quickly become adapted and oriented, and then begin their natural foraging and migrations.

The summary results of the head-start research at the NMFS Galveston Laboratory are listed in Table 2. The Galveston head-start research project has been very successful in developing a reliable method of rearing Kemp's ridleys and in extensive research on diseases and pathological conditions and their resolutions. The overall project costs are high, averaging more than $100.00 per yearling turtle released.

Table 2.—Kemp's ridley sea turtle head-start research project summary, by year-class[1].

Year-class	Hatchlings received: Inclusive dates	Weight (g)	No. alive	No. dead	Total number	Tagged turtles released: Number	Percent[2]	Recoveries: Number	Percent[3]
1978	6 July-11 August	16.9	3,080	1	3,081	2,019	65.6	75	3.7
1979	26 June-23 August	18.1	1,843	3	1,846	1,345	73.0	17	1.3
1980	24 June-14 July	16.2	1,815	7	1,822	1,723	94.9	85	4.9
1981	12 July-22 August	20.6	1,864	1	1,865	1,639	87.9	46	2.8
1982	6 July-16 August	19.2	1,524	0	1,524	1,325	86.9	149	11.2
1983	8 July-12 August	15.0	250	0	250	190	76.0	8	4.2
1984	24 July-27 July	16.4	1,441	106	1,547	1,017	70.6	5	0.5
1985	9 July-7 August		1,684	8	1,692				
Totals			13,501	126	13,627	9,258		385	4.1

[1]As of 18 September 1985.
[2]Based on number received alive; overall survival is 82.2 percent.
[3]Based on number released.

Habitat Search

The low population numbers and the relatively elusive habits of the Kemp's ridley sea turtle have hindered understanding of the real nature and severity of threats to the species. The Kemp's Ridley Research and Management Plan produced the Kemp's Ridley Habitat Search Project to seek and record all possible occurrences of Kemp's ridley, concentrated in the U.S. section of the Gulf of Mexico and extending up the Atlantic seaboard. A cadre of network participants has been developed, and their reports will significantly improve our knowledge of occurrences and habits of Kemp's ridleys in U.S. waters. Meanwhile, the Sea Turtle Stranding and Salvage Network for the Gulf and Atlantic Coasts of the United States, activated in 1980, continues to record strandings, alive and dead, and some incidental captures of Kemp's ridleys.

TED

Shrimp trawling has been implicated as a significant cause of sea turtle mortality through incidental catch of sea turtles while trawling and dragging the turtles long enough and with sufficient stress to kill them. An estimated 843 Kemp's ridleys were so caught and an estimated 275 subsequently killed per year for the 1980-82 period in U.S. shrimp trawling areas of the Gulf and Atlantic. The numbers of Kemp's ridleys caught and killed by shrimp trawling in the waters of Mexico are unknown despite efforts by the Sea Turtle Working Group to investigate this. It has been estimated that the total annual kill of Kemp's ridleys by human causes is twice as large in Mexican waters as in the U.S. waters.

The invention and improvement of the TED (Turtle Excluder Device) in 1984-85 by the NMFS Pascagoula Laboratory has given fishery managers the capacity to reduce sea turtle incidental catch and kill by shrimp trawling by an estimated 97 percent. Through 1985, the TED had been demonstrated to most shrimpers around the United States, and two limited demonstrations had been made in Mexico. Actual use of the TED in the United States and Mexico was very limited through 1986.

WATS II

The Sea Turtle Working Group has supported the objectives and data collections of the Western Atlantic Turtle Symposium (WATS) since its inception in 1979. Group members participated in preparation of the National Report for the United States and for Mexico that were presented to the Symposium (July 1983) and published in the Proceedings. They prompted and supported the sea turtle nesting beach aerial surveys from Cape Hatteras through Quintana Roo. They serve as cadre of WATS II in continuing to solicit sea turtle data collection from all 38 of the WATS area countries, and will participate in the Second Symposium, 12-16 October 1987, in Mayaguez, Puerto Rico.

U.S. Fish Exports and Imports Set Records in 1986

Exports of edible U.S. fish rose a whopping 30 percent in 1986 to an all-time high of $1.3 billion with the sale of a record 735 million pounds of seafood to foreign buyers, NOAA's National Marine Fisheries Service has announced. The Commerce Department agency noted, however, that imports of edible fish also set a record, with the United States purchasing $4.8 billion worth of seafood from abroad, $772 million more than in 1985. The volume of these imports totalled 3 billion pounds, also a record, according to NMFS statistics.

Imports of nonedible fishery products added another $2.8 billion onto the foreign trade bill. These consisted chiefly of high-value-added items like marine-derived chemicals, jewelry using pearls or coral, and leather goods made from seals and other aquatic animals. U.S. exports of nonedible fishery products were worth only $66 million according to NMFS data.

Imports

U.S. imports of edible fishery products in 1986 were valued at a record $4.8 billion, $771.8 million higher than the previous record for value established in 1985 (Table 1). The quantity of edible imports was a record at 3.0 billion pounds, 224.9 million pounds more than the previous record quantity imported in 1985.

Shrimp, Tuna Records

The quantity of shrimp imported in 1986 established a record with 400.1 million pounds, 41.2 million pounds more than the previous record quantity imported in 1985. Valued at $1.4 billion, $281.4 million more than the 1985 value, shrimp imports accounted for 30 percent of the value of total edible imports. Imports of fresh and frozen tuna, 563.6 million pounds, increased 86.3 million pounds more than the 478.8 million pounds imported in 1985. Imports of canned tuna not in oil increased for the eighth consecutive year with a record 236.3 million pounds, an increase of 22.7 million pounds over the previous record year of 1985.

Table 1.—Summary of imports and exports of fishery products, 1935-86.

	Imports				Exports			
	Edible products		Nonedible products	Total imports	Edible products		Nonedible products	Total exports
Year	Quantity[1]	Value[2]	Value[2]	Value[2]	Quantity[1]	Value[2]	Value[2]	Value[2]
1935	324,732	$27,535	$ 8,697	$36,232	119,687	$12,875	$1,499	$14,374
1936	371,206	30,357	11,516	41,873	111,259	12,263	951	13,214
1937	364,668	33,911	16,725	50,636	119,068	13,729	838	14,567
1938	302,624	28,349	10,958	39,307	118,029	13,798	617	14,415
1939	346,240	32,404	13,595	45,999	124,974	13,580	627	14,207
1940	302,518	29,073	12,757	41,830	144,804	17,115	670	17,785
1941	305,875	28,040	12,941	40,981	215,990	21,479	529	22,008
1942	277,199	28,984	10,584	39,568	167,080	27,876	4,039	31,915
1943	324,476	43,689	23,494	67,182	239,260	43,244	5,290	48,534
1944	339,431	53,431	24,987	78,418	112,230	31,929	4,011	35,940
1945	404,768	76,434	24,820	101,254	135,979	30,855	7,655	38,510
1946	473,539	89,986	39,727	129,713	200,398	38,353	1,616	39,969
1947	407,636	83,275	26,700	109,975	207,486	49,281	3,555	52,836
1948	472,742	111,660	44,988	156,648	95,085	21,020	3,382	24,402
1949	470,517	113,753	37,861	151,614	146,660	29,212	5,838	35,050
1950	639,725	158,414	39,882	198,296	121,623	18,856	8,618	27,474
1951	646,668	158,363	54,094	212,457	164,624	27,072	8,659	35,731
1952	705,118	183,121	57,308	240,429	62,056	15,511	6,436	21,947
1953	726,195	195,869	49,611	245,480	69,308	17,084	10,794	27,878
1954	804,054	203,722	48,687	252,409	62,724	16,238	15,289	31,527
1955	780,185	208,973	49,896	258,869	109,750	24,923	15,054	39,977
1956	801,655	234,699	48,031	282,730	101,918	22,939	16,564	39,503
1957	900,227	252,788	46,487	299,275	85,221	20,549	15,403	35,952
1958	1,020,326	283,822	46,959	330,781	65,468	19,440	11,564	31,004
1959	1,141,114	314,650	55,467	370,117	80,688	26,747	17,495	44,242
1960	1,095,014	310,596	52,685	363,281	61,454	25,622	18,543	44,165
1961	1,061,662	335,757	61,301	397,058	40,137	19,594	15,116	34,710
1962	1,255,532	405,832	83,975	489,807	56,530	22,470	13,258	35,728
1963	1,196,977	399,928	100,784	500,712	64,745	30,376	26,229	56,605
1964	1,318,099	433,674	130,569	564,243	94,835	42,878	21,326	64,204
1965	1,398,778	479,412	121,492	600,904	96,444	49,308	20,175	69,483
1966	1,593,614	568,091	151,611	719,702	109,604	62,882	21,931	84,813
1967	1,470,437	538,301	169,582	707,883	107,940	67,524	14,685	82,209
1968	1,741,365	643,165	179,504	822,669	90,808	56,845	10,912	67,757
1969	1,706,571	704,809	139,484	844,293	140,646	86,474	18,059	104,533
1970	1,873,300	812,530	224,880	1,037,410	140,375	93,878	23,606	117,484
1971	1,785,470	887,070	187,131	1,074,201	171,816	113,637	25,608	139,245
1972	2,341,138	1,233,292	261,119	1,494,411	171,642	134,188	23,720	157,908
1973	2,416,193	1,398,484	184,649	1,583,133	238,942	241,866	57,302	299,168
1974	2,266,880	1,495,380	215,498	1,710,878	178,011	194,966	67,166	262,132
1975	1,913,089	1,367,180	269,919	1,637,099	218,152	267,360	37,369	304,729
1976	2,228,091	1,913,922	414,264	2,328,186	240,866	329,810	54,880	384,690
1977	2,176,189	2,078,171	555,435	2,633,606	331,059	473,375	47,121	520,496
1978	2,410,673	2,256,314	829,637	3,085,951	448,312	831,654	73,880	905,534
1979	2,358,920	2,671,860	1,136,931	3,808,791	554,294	1,022,335	62,162	1,084,497
1980	2,144,928	2,686,721	961,731	3,648,452	573,896	904,363	101,791	1,006,154
1981	2,272,474	3,034,206	1,171,805	4,206,011	667,272	1,072,765	84,230	1,156,995
1982	2,225,474	3,202,408	1,321,170	4,523,578	657,246	998,873	60,011	1,058,884
1983	2,386,771	3,626,704	1,502,668	5,129,372	601,913	907,688	[3]113,804	1,021,492
1984	2,454,287	3,742,333	2,141,060	5,883,393	574,124	842,349	106,490	948,838
1985	2,754,018	4,064,334	2,614,252	6,678,586	648,146	1,010,268	73,846	1,084,114
1986	[3]2,978,905	[3]4,813,488	[3]2,812,805	[3]7,626,293	[3]735,026	[3]1,289,807	66,289	[3]1,356,096

[1]Thousands of pounds
[2]Thousands of dollars
[3]Record

Fillets, Blocks Up

Imports of fresh and frozen fish fillets and steaks amounted to a record 538.5 million pounds, an increase of 1.8 million pounds over 1985. Regular and minced block imports were 363.9 million pounds, an increase of 29.8 million pounds from 1985. Edible imports consisted of 2.4 billion pounds of fresh and frozen products valued at $4.2 billion, 438.8 million pounds of canned products valued at $500.4 million, 68.1 million pounds of cured products valued at $80.0 million, and 14.0 million pounds of other products valued at $24.6 million. Analog products (surimi) amounted to 34.3 million pounds valued at $58.5 million in 1986, compared with 33.7 million pounds valued at $48.2 million in 1985.

Imports of nonedible fishery products were valued at a record $2.8 billion—$198.6 million more than the $2.6 billion imported one year earlier. Total value of edible and nonedible products resulted in a record import value of $7.6 billion in 1986—$947.7 million more than the previous record in 1985, when $6.7 billion of fishery products were imported.

Exports

U.S. exports of edible fishery products of domestic origin were a record 735.0 million pounds valued at a record $1.3 billion, compared with 648.1 million pounds valued at $1.0 billion exported in 1985. Fresh and frozen items were 615.5 million pounds valued at $1.0 billion, increases of 71.2 million pounds and $260.2 million compared with 1985. Fresh and frozen exports consisted principally of 293.5 million pounds of salmon valued at $552.3 million and 90.4 million pounds of herring valued at $70.2 million.

Canned Products Up

Canned items were 79.6 million pounds valued at $132.2 million, up 21.1 million pounds and $35.8 million from 1985 levels. Salmon was the major canned item exported, with 59.4 million pounds valued at $101.2 million. Cured items were 39.4 million pounds valued at $112.9 million, decreases of 5.4 million pounds and $16.6 million compared with 1985. Cured exports consisted mainly of salmon and herring roe, which amounted to 29.8 million pounds valued at $91.2 million. The $154.9 million received for U.S.-Flag vessel catches transferred onto foreign vessels in the U.S. EEZ in joint venture operations are not included in the export statistics.

Nonedible Products Down

Exports of nonedible products were valued at $66.3 million—$7.6 million less than the $106.5 million exported in 1985. Exports of menhaden oil amounted to 188.9 million pounds valued at $19.8 million, decreases of 89.3 million pounds and $16.2 million compared with 1985. Thus, menhaden oil exports accounted for 29.9 percent of the value of total nonedible exports in 1986. The total value of edible and nonedible exports was $1.4 billion—an increase of $272.0 million compared with 1985. (Source: CFS 8401.)

Economists with NOAA's National Marine Fisheries Service said they expect recent trade concessions by other major U.S. seafood buying countries, especially Japan, to help boost U.S. exports in 1987 (see related article below).

New Trade Concessions Could Mean Millions for U.S. Fish Exporters

The Japanese have slashed trade restrictions on U.S. fishery products in a move that could mean as much as $400 million annually in increased sales for American exporters of processed Alaska pollock and Pacific herring. The shift followed a week-long meeting in March in Tokyo between the Japanese and U.S. representatives from the Commerce Department's National Oceanic and Atmospheric Administration (NOAA) and the Office of the U.S. Trade Representative.

The settlement will mean that American producers will have virtually unrestricted access to Japanese markets for processed Alaska pollock, mostly surimi, and for Pacific herring. The U.S. exported less than $50 million worth of these products to Japan last year. NOAA estimates that the agreement should result in $35 million in new exports to Japan this year, growing to $300 million to $400 million in the early 1990's, as the U.S. industry develops its market opportunities in Japan. Fishermen and processors in Alaska and Washington will be the chief beneficiaries of these new markets, NOAA said.

Fisheries trade experts with NOAA forecast that within the next 5 years the United States will be shipping to Japan annually about 100,000 tons of surimi. Surimi, a high-value-added pollock product with a billion-dollar market in Japan, is used as an ingredient in many traditional Japanese foods. In 1986, the U.S. exported less than 500 tons of surimi to Japan. Previously, Japan had severely impeded the import of processed pollock from the United States and had required restrictive import licenses for U.S. shippers, NOAA said.

The new trade agreement provided that Japan will create a new quota category for Pacific herring, which it will set each year at a level that corresponds to total U.S. production. Half of this quota will be available on a first-come-first-served basis for any importer with a contract and a pending shipment from a U.S. supplier. According to NOAA, the settlement should establish more competitive bidding for U.S. herring supplies, resulting in higher prices for U.S. exporters.

Basic Exporting Guide

The U.S. Commerce Department has announced the publication of a new edition of "A Basic Guide to Exporting." The 130-page guide, referred to as the "exporters bible" by Alexander Good, director of the U.S. and Foreign Commercial Service, provides facts, terms, techniques, ideas, and information for successful international market strategies. A checklist of export regulations, customs, benefits, and tax incentives to aid export businesses is included. The guide is available for $8.50 (stock number: 003-009-00487-0) from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, Telephone (202)783-3238, or from most GPO Bookstores.

Americans Eat More Seafood Than Ever

In 1986, and for the third consecutive year, Americans ate a record amount of seafood, as they consumed 14.7 pounds per person and beat the 1985 record amount of 14.4 pounds per person, according to the National Oceanic and Atmospheric Administration (NOAA). Record consumption of shrimp and the highest consumption of canned fish, primarily tuna, in 50 years helped boost the per capita figure, the Commerce Department agency said. NOAA estimates that recreational fishermen added another 3-4 pounds of seafood to the American diet in 1986.

According to marketing experts with NOAA's National Marine Fisheries Service (NMFS), the record per capita figure reflects a trend of steadily increasing fish and shellfish consumption that began in the late 1970's when the typical American ate only about 11 pounds of seafoods each year. The NMFS added that Americans are also taking advantage of increased availability of seafoods at restaurants and supermarkets, and the appearance of nontraditional species, such as Alaska pollock and amberjack. In addition, the agency reported, news that eating fish may help prevent heart disease and other ailments has helped seafood consumption. The figures reflect the consumption of edible meat, rather than the weight of the whole fish, the NMFS added.

Leading U.S. Fishing Ports for 1986 Listed

New Bedford, Mass., and Cameron, La., were the leading fishing ports in the United States in 1986, the National Oceanic and Atmospheric Administration (NOAA) has announced. For the fourth consecutive year New Bedford topped all other cities in the value of the fish landed, the Commerce Department agency said. There, fish and shellfish worth $106 million were landed in 1986, up slightly from the $103 million figure in 1985. The Louisiana port of Dulac-Chauvin was second in value with $71 million worth of fish landed.

Cameron, La., led other cities in terms of volume with 617 million pounds, down from 674 million pounds in 1985. Most of the landings were the lower valued but industrially important menhaden. Two Texas ports saw dramatic shifts in landed value in 1986. Brownsville-Port Isabel's landings went from $50 million in 1985 to $69 million last year, and Aransas Pass-Rockport's landings jumped from $43 million to $60 million in value during the same period. The 10 leading U.S. ports in volume (millions of pounds) and value (millions of dollars) of fish and shellfish landed in 1986, with 1985 figures for comparison, are shown in Tables 1 and 2, respectively.

Table 1.—The 10 leading U.S. ports in volume (millions of pounds) of fish and shellfish during 1985 and 1986.

Port	Volume of landings 1985	1986
Cameron, La.	673.6	616.8
Pascagoula-Moss Point, Miss.	423.2	365.5
Empire-Venice, La.	224.5	317.6
Intercoastal City, La.	N/A[1]	298.9
Dulac-Chauvin, La.	398.6	294.6
Los Angeles, Calif.	150.3	187.4
Kodiak, Alaska	96.1	124.0
Gloucester, Mass.	116.5	110.0
Beaufort-Morehead City, N.C.	133.2	98.9
Dutch Harbor-Unalaska, Alaska	106.3	88.3

[1]Data not available.

Table 2.—The 10 leading U.S. ports in value (millions of dollars) of fish and shellfish during 1985 and 1986.

Port	Value of landings 1985	1986
New Bedford, Mass.	103.2	106.0
Dulac-Chauvin, La.	59.9	71.0
Kodiak, Alaska	65.8	70.2
Brownsville-Port Isabel, Tex.	49.6	69.3
Aransas Pass-Rockport, Tex.	43.0	60.3
Empire-Venice, La.	34.3	47.1
Bayou La Batre, Ala.	30.4	43.3
Golden Meadow-Leeville, La.	23.5	40.0
Petersburg, Alaska	N/A[1]	38.1
Gloucester, Mass.	37.1	37.8

[1]Data not available.

Fish Catch Noted for New England, Middle Atlantic

Preliminary figures for 1986 commercial landings of fish and shellfish in the Mid-Atlantic States of New York, New Jersey, Pennsylvania, Delaware, Virginia, and Maryland were 775 million pounds, valued at $245 million, according to Allen E. Peterson, Jr., Director of the National Marine Fisheries Service's Northeast Fisheries Center in Woods Hole, Mass. These 1986 figures are down 203 million pounds and up $6 million from the 1985 figures (Tables 1-3).

Table 1.—Weights (millions of pounds) and values (millions of dollars) of Mid-Atlantic fish and shellfish landings,[1] state-by-state, for 1985 and 1986.

State	1985 Weight	1985 Value	1986 Weight	1986 Value
Virginia	725	80	530	80
New Jersey	108	61	108	67
Maryland	101	56	89	51
New York	39	40	43	45
Delaware	5	2	5	2
Pennsylvania	<0.5	<0.5	<0.5	<0.5
Total	978	239	775	245

[1]Landings of fish in live weight; landings of most shellfish in meat weight; preliminary data.

Table 2.—Weights (millions of pounds) and values (millions of dollars) of Mid-Atlantic fish and shellfish landings,[1] port-by-port, for 1985 and 1986.

Port	1985 Weight	1985 Value	1986 Weight	1986 Value
Cape May-Wildwood, NJ	48	25	53	28
Ocean City, MD	25	11	29	12
Hampton Roads area, VA	24	25	25	24
Atlantic City, NJ	22	12	22	13
Point Pleasant, NJ	17	6	15	6
Chincoteague, VA	12	7	14	8
C. Charles-Oyster, VA	11	5	11	4
Montauk, NY	8	9	11	13
Hampton Bays, NY	9	6	8	6
Mattituck, NY	<5	<3	5	3
Greenport, NY	<5	<3	4	4

[1]Landings of fish in live weight; landings of most shellfish in meat weight. Also, because of the Federal Privacy Act, landings at major ports are not included if there are less than three processors at those ports (e.g., Reedville, Va.). Preliminary data.

Table 3.—Weights (millions of pounds) and values (millions of dollars) of Mid-Atlantic fish and shellfish landings,[1] species-by-species, for 1985 and 1986.

Species	1985 Weight	1985 Value	1986 Weight	1986 Value
Hard blue crabs	102	29	86	28
Surf clams	67	33	69	37
Ocean quahogs	42	13	43	13
Squids	9	13	13	4
American oysters	14	25	12	24
Summer flounder (fluke)	14	13	11	13
Silver hake (whiting)	14	3	8	2
Scup (porgy)	5	3	7	4
Sea scallops	5	22	7	29
Atlantic mackerel	3	0.3	6	1

[1]Landings of fish, squid, and blue crab in live weight; landings of other shellfish in meat weight; preliminary data.

Table 4.—Weights (millions of pounds) and values (millions of dollars) of fish and invertebrate landings[1] in New England, state-by-state, for 1985 and 1986.

State	1985		1986	
	Weight	Value	Weight	Value
Massachusetts	298.2	231.5	271.3	243.6
Maine	175.5	100.9	168.2	108.4
Rhode Island	103.8	69.9	101.6	75.1
New Hampshire	7.6	5.3	7.9	6.2
Connecticut	6.7	11.9	6.7	15.6
Total	589.8	419.5	555.7	448.9

[1]Landings of fishes in live weight; landings of invertebrates in meat weight; preliminary data.

Table 5.—Weights (millions of pounds) and values (millions of dollars) of fish and invertebrate landings in New England, port-by-port, for 1985 and 1986.

Port	1985		1986	
	Weight	Value	Weight	Value
Gloucester, MA	116.5	37.1	109.6	37.8
New Bedford, MA	90.6	103.2	65.8	106.0
Pt. Judith, RI	56.8	28.0	52.1	28.5
Rockland, ME	58.6	11.1	42.7	9.1
Portland, ME	36.1	17.2	34.3	22.4
Boston, MA	19.8	12.1	30.7	19.0
Newport, RI	16.8	13.7	11.6	12.8

[1]Preliminary data.

Table 6.—Weights (millions of pounds) and values (millions of dollars) of fish and invertebrate landings[1] in New England, species-by-species, for 1985 and 1986.

Species	1985		1986	
	Weight	Value	Weight	Value
Atlantic herring	57.0	2.9	70.4	3.8
Atlantic cod	82.3	34.7	60.8	35.6
American lobster	43.7	107.4	42.7	112.1
Pollock	43.5	6.8	32.1	14.0
Silver hake (whiting)	31.0	5.4	31.5	5.9
Yellowtail flounder	23.6	19.6	22.2	20.5
Winter flounder	21.5	18.5	16.3	16.8
White hake	16.2	3.4	11.9	4.8
Sea scallop	10.2	50.0	11.5	61.2
Haddock	14.4	13.5	10.9	10.9
Northern shrimp	9.3	4.0	10.3	6.6
Summer flounder (fluke)	9.9	10.5	10.0	13.1
Scup	8.8	5.0	8.0	4.3
Swordfish	2.6	7.0	2.2	7.4

[1]Landings of fishes in live weight; landings of invertebrates in meat weight; preliminary data.

Table 7.—Weights (millions of pounds) and values (millions of dollars) of American lobster landings[1] in New England, state-by-state, for 1985 and 1986.

State	1985		1986	
	Weight	Value	Weight	Value
Maine	20.1	45.0	19.7	46.2
Massachusetts	15.6	40.1	15.0	41.0
Rhode Island	5.1	14.6	5.1	16.7
Connecticut	1.7	5.0	1.8	5.4
New Hampshire	1.2	2.7	1.1	2.8
Total	43.7	107.4	42.7	112.1

[1]Preliminary data.

Meanwhile, preliminary 1986 figures for commercial landings of New England fishes and invertebrates were 555.7 million pounds, valued at $448.9 million. These figures are down 34.1 million pounds and up $29.4 million from the 1985 totals, Peterson noted, for the States of Connecticut, Maine, Massachusetts, New Hampshire, and Rhode Island.

Landings of such traditionally important groundfishes as cod, haddock, and yellowtail flounder decreased by 26.4 million pounds in 1986 compared with 1985, accounting for most of the overall decrease last year. Tables 4-6 compare the weights and values of New England landings in 1985 and 1986 on a state, port, and species basis, while Table 7 provides data on landings of American lobsters in each of the New England states. Overall, the 1986 landings of lobster were 42.7 million pounds (vs. 43.7 million pounds in 1985), valued at $112.1 million (vs. $107.4 million in 1985).

Federal Procurement Fact Sheets Available

A packet of fact sheets has been prepared by NMFS to aid U.S. seafood companies interested in selling seafood to Federal agencies. The fact sheets include basic information of Federal purchasing requirements for: The Department of Defense, Department of Justice Bureau of Prisons, Health and Human Services, Veterans Administration, and the Department of Agriculture. There are also specific contacts identified within each agency if more detailed information is needed. U.S. firms interested in copies should write to: Federal Procurement Fact Sheets, NMFS, Utilization and Development Branch, P.O. Box 1109, Gloucester, MA 01931.

Storm Impacts on Fish Studied by NOAA Agencies

Scientists from the National Oceanic and Atmospheric Administration (NOAA) have been flying through severe storms over Alaskan waters to measure their effect on the transport of fish eggs and larvae from their spawning grounds, the Commerce Department agency reports. Starting about 15 February, a NOAA research aircraft operating from Anchorage began flying patterns through severe storms on successive days, according to Bernard A. Walter of NOAA's Pacific Marine Environmental Laboratory in Seattle.

The scientists are trying to predict fast-developing storms over the Bering Sea and Gulf of Alaska, and then document their effect on area waters and marine life. Data are being collected aboard the aircraft and from instrument packages dropped into the ocean, which describe water temperature, depth of its mixed layer, vertical current profiles, and other factors. Meteorological analyses are made just before and after the flights, according to Melvyn Shapiro of NOAA's Environmental Research Laboratories in Boulder, Colo. NOAA weather satellites, and ocean buoys moored in the area will also provide information.

The project is part of a larger, multiyear Fisheries-Oceanography Coordinated Investigations program involving the Environmental Research Laboratories and the National Marine Fisheries Service. The program, one with significant economic implications, is designed ultimately to identify environmental factors which can be monitored and from which the size of fisheries can be forecast. That capability would substantially aid operational planning by the fishing industry.

NOAA Wins Its First Marine Sanctuary Case

The National Oceanic and Atmospheric Administration (NOAA) announced early this year an out-of-court settlement in which the United States will receive $6,275,000 over the next 15 years from attorneys for the 400-foot freighter MV *Wellwood*, which ran aground on Molasses Reef in the Key Largo National Marine Sanctuary off the Florida Keys on 4 August 1984. The U.S. Department of Justice had filed suit

alleging damage to nature resources. It also sought civil penalties, and recovery of U.S. Coast Guard salvage costs. The case had been scheduled to go to trial in U.S. District Court in Miami in early 1987.

Commenting on NOAA's first court action over damages to natural resources in a national marine sanctuary, Peter Tweedt, Director of NOAA's Office of Ocean and Coastal Resource Management in Washington, D.C., said, "Boaters and ship operators should be aware of the damage that can be done to fragile marine resources when marine sanctuary regulations are violated. This settlement should demonstrate that this administration will take whatever legal steps are necessary to ensure that these nationally significant marine areas are protected."

The grounding of the M/V *Wellwood* resulted in extensive, long-term damage to large areas of slow growing coral formations in the Key Largo sanctuary. Despite round-the-clock efforts by the Coast Guard and private salvage firms, the vessel remained aground for 12 days. NOAA research scientists assessing damages to the reef, expect it will be many years before there is any significant recovery by the reef. The Justice Department has also filed a $500,000 claim against a Panamanian-registered freighter, the MV *Mini Laurel*, its owner, and captain for striking Molasses Reef on 11 December 1986. Initial studies by NOAA indicate that the 215-foot vessel caused less damage than the *Wellwood*.

NOAA, Massachusetts Make Monetary Settlement in Superfund Law Case

The Commerce Department's National Oceanic and Atmospheric Administration (NOAA) and the state of Massachusetts agreed earlier this year to a $2 million settlement with AVX Corporation of Great Neck, N.Y., to resolve any liability for damages to coastal resources and damage assessment costs in New Bedford, Mass., caused by the company's alleged disposal of polychlorinated biphenyls (PCB's). The settlement, filed 4 March 1987 with the U.S. District Court in Boston, must be approved by Judge William D. Young. If approved, it would be the first Federal monetary recovery for damages to natural resources under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, commonly known as the Superfund Law. NOAA and Massachusetts would use the money to restore the damaged resources for public use and recoup assessment costs.

A 30-day period of public comment is provided by the Justice Department before the settlement can be approved. Acting as public trustees, NOAA filed suit in Federal district court in Boston in 1983, joined by Massachusetts, alleging that over a 25-year period AVX Corporation disposed of toxic industrial wastes—PCB's—in the Acushnet River estuary, which empties into New Bedford harbor. They alleged that the contamination hurt commercial and recreational fishing, public beaches, and other harbor amenities. NOAA and Massachusetts claim the damages continue because the chemicals persist in the environment and accumulate in living organisms.

The Environmental Protection Agency (EPA), which is conducting an investigation of the contamination, also joined the suit in 1984 to recover its costs to study and clean up the polluted area. Recovery of EPA's costs will be resolved in subsequent proceedings. The trial of a former owner of the electrical capacitor manufacturing plant that is alleged in the suit to be one of the sources of the PCB pollution, Belleville Industries of New Bedford, Mass., was scheduled before Judge Young for late March or in early April. The current owner of the plant, Aerovox, Inc., of New Bedford, will also participate in the proceedings. In the same case, Federal Pacific Electric Company and Cornell-Dubilier Electronics Company, both of Newark, N.J., are scheduled to go to trial in 1988 for alleged PCB damage from a similar manufacturing facility in New Bedford.

Clam and Spiny Lobster Poaching Arrests Made

A combined State-Federal covert investigation into the illegal sale and interstate transport of South Carolina clams prompted arrest warrants for 25 people in South Carolina, late last year, according to the Southeast Regional Directorate for the National Marine Fisheries Service. Law enforcement officials from the South Carolina Wildlife and Marine Resources Department, the South Carolina Department of Health and Environmental Control and the National Marine Fisheries Service, announced the results of the undercover investigation into the illegal trade in clams, code named Operation SOCKO.

"This year-long undercover investigation by our three agencies netted receipts for $775,147.72 worth of clams," said W. K. Chastain, Director of the State Wildlife Department's Law Enforcement Division. "These receipts reflect the sale—90% out-of-state—of 5,242,905 clams in 250-count bags between December 1983 and August 1986. All were harvested from South Carolina coastal waters.

"This figure of more than three quarters of a million dollars is very conservative, reflecting only a small part of the total black market in hard clams," Chastain said, "since no records were kept for many additional shipments bootlegged out of the state." The investigation began as a result of cases made by Wildlife Conservation Officers and Department of Health and Environmental Control Shellfish Officers, and information obtained by the National Marine Fisheries Service, plus numerous complaints by private citizens.

"The size and nature of the problem led us to believe that the investigation could not be handled through regular law enforcement means, but through a cooperative covert operation," said Jack Brawner, then director of the NMFS Southeast Regional Office. State and federal officials cautioned, however, that all charges listed in the indictments, as in any indictment, are merely accusations. All defendants are presumed innocent unless and until proven guilty.

The ongoing investigation indicated that these 25 individuals may be responsible for 707 counts of violations of state wildlife codes, 200 counts of state health codes, and 300 counts of the Federal Lacey Act, which forbids the interstate sale of fish and wildlife taken in violation of state law. Maximum criminal penalties against individuals for Lacey Act violations are $250,000 and 5 years in prison.

"The combined force of state and federal officers, working undercover, was able to enter the world of these black market clam dealers and thoroughly document most of their operation," Chastain said. Most of the clams shipped out of the state were being dug at night using hand tools. A productive night could easily yield $1,000 worth of clams destined for distant markets.

The arrests were timed to take place during a morning high tide when most of the suspects would be at home. Conservation officers were also posted at several landings known to be used by the suspects in the event that arrests would need to be made on the water. "The investigation is continuing and additional arrests and charges are expected," Chastain said.

In other law enforcement action, a fish dealer in Big Pine Key, Fla., was indicted by a Federal grand jury on charges of possession and sale of undersized spiny lobsters. As a result of the Federal indictment, the dealer was arrested by Federal agents on 25 November 1986 for alleged violation of the Lacey Act.

Information for the indictment came from an investigation by special agents of the National Marine Fisheries Service and officers of the Florida Marine Patrol. Numerous purchases, sales, and interstate shipments of illegal lobsters were alleged. Florida law prohibits the possession of spiny lobsters with a tail length of less than 5½ inches.

According to State and Federal officials, the minimum size limitation is a key element in the conservation and management of spiny lobsters. Harvesting spiny lobsters before they have an opportunity to grow to sexual maturity seriously endangers the future of Florida's spiny lobster fishery and denies legitimate commercial and recreational fishermen the opportunity to harvest lobsters at the legal size. Again, Federal officials caution that all charges listed in the indictment, as in any indictment, are merely accusations.

Commerce Department Medals Are Awarded

In ceremonies late last year, the U.S. Department of Commerce awarded its highest honorary award, the gold medal, to 28 individuals, including five NOAA employees for lifesaving acts: Douglas P. Anderson, Mark H. Bushnell, Daniel J. Parry, Robert J. Roddy, and Dean L. Smehil. Earning a gold medal for studies of dynamics and chemistry of the middle atmosphere was Jerry D. Mahlman, and Charles J. Neumann earned the gold medal for achievement in statistical/dynamic tropical cyclone track prediction modeling.

The Department's second highest honorary award, the silver medal was granted to 69 individuals and 5 offices for outstanding work. Twenty-four NOAA employees were presented with the silver medal: Michael D. Abell, William E. Carter, John Ross MacKay, Douglas S. Robertson, Arthur C. O'Shaughnessy, Michael D. Cox, Stephen M. Billcheck, Paul M. Gilkerson, Leo R. Harrison, Jr., Marvin O. Hill, David A. Keller, Kenneth S. Mack, Elnora G. Markle, Alfred L. Purdy, Jr., Robert M. Tibi, Russell Koffler, Richard M. Davis, William Propest, David E. McGuirk, Robert O. Brines, Jr., Roger W. Bissinger, Rober C. Elvander, Robert E. Saffle, and Francis D. Moran.

Research Scientists Earn Excellence Award

Each year the American Oil Chemists' Society presents an award for the most outstanding poster session at its annual meeting. The award is based on scientific content and communication. At the Society's 1986 meeting in Honolulu, Hawaii, the award was won by the paper, "The Use of Supercritical Fluid Cardon Dioxide to Fractionate Fatty Acid Esters Derived from Menhaden Oil." The text and visual materials were written and compiled by William Nilsson, Virginia Stout, Erich Gauglitz, Jr., Joanne Hudson, and John Spinelli of the NMFS Northwest and Alaska Fisheries Center's Utilization Research Division.

Polyphosphate Use in Canned Salmon

In May 1986, the Utilization Research Division (URD) of the NMFS Northwest and Alaska Fisheries Center sponsored an Industry Workshop demonstrating the use of sodium polyphosphate (or condensed phosphates) in canned salmon in reducing curd formation and improving texture, color, and flavor. The workshop was attended by members of the salmon canning industry, process chemical and equipment manufacturers, and the trade press. Workshop panelists were John E. Wekell (URD), Lee Patton (Alaska Seafood Marketing Institute, ASMI), and Al Duzenback (Food and Drug Administration, FDA). Wekell discussed the polyphosphate treatment developed in the Utilization Research Division, while Duzenback discussed the FDA regulations on standards of identity and procedures for amending these regulations, and Patton discussed ASMI marketing studies showing changes in consumer attitudes toward canned salmon.

The ASMI studies described by Patton dramatically illustrated the new forces facing the canned salmon industry. Changing attitudes of consumers has led to the demand for more fresh/frozen salmon than for the canned product. For the past several years, the salmon industry in Alaska has begun freezing more salmon than it cans. The canning of samon places a large burden on process lines because of the very large landings that occur in very short spaces of time. Therefore capacity to handle such input is necessarily large but is used for only very short periods of time, e.g., 3-4 months. The industry would like to smooth out production of canned salmon throughout the year in place of a highly concentrated season. If frozen fish could be canned, production could be easily spread out through the year.

Unfortunately, the use of frozen fish in canning leads to a product having large amounts of surface curd and relatively dry texture. URD work has shown that the use of polyphosphate dips or sprays can effectively reduce the formation of unsightly curd in canned salmon when frozen pink or sockeye salmon are thawed and then processed for canning.

Curd formation is a visual defect commonly observed in the cooking of frozen meats, such as beef, poultry, and fish. The curd is caused by heat coagulation of protein in the drip that is present in all thawed frozen products. In addition, frozen edible tissue, when it is cooked, usually displays some loss of texture quality, e.g., loss of juiciness, a dry or "cardboard" feeling in the mouth during chewing. Careful attention to the processing of the tissue prior to freezing and control of the freezing rate can help to reduce the quality loss observed in the finished cooked product; however, some tissues, particularly from fish appear to be more susceptible to freeze-thaw damage than either poultry of beef. For example, salmon held under the best of cold storage conditions (on ice) for prolonged periods (1 week), when canned, will produce significant amounts of curd in the finished product.

URD work has shown that frozen salmon could be thawed and successfully processed into a canned product with significant reduction in curd and an improvement of both texture and flavor. The application of polyphosphates to canned salmon was demonstrated on three different styles of salmon pack: Traditional steak pack, a boneless-skinless steak pack, and a boneless-skinless small chunked pack. It was found that dipping or soaking the cut pieces of salmon in a solution of 10-15 percent polyphosphate and 2 percent salt for periods ranging from a very brief "in and out" to 2 minutes could effect the curd reduction. In the case of the smaller chunks, a spray of polyphosphate/salt could be used in place of the dip.

The use of polyphosphate/salt dips was particularly effective on the boneless/skinless product. Not only was there a substantial reduction in curd formation, but a very significant improvement in the texture and flavor of salmon. For example, usually the dark meat associated with the lateral line in canned salmon has a very pronounced strong flavor (sometimes rancid). However, in the polyphosphate-treated fish, this dark meat was indistinguishable from the other meat. In the small chunked product, treated with polyphosphate and canned with salt, texture had a pronounced moist, soft texture compared with the untreated controls. In both boneless/skinless products (steak and small chunk), some slight improvement in the color appearance of the product was also observed.

Application of this process in the salmon industry is now dependent on two factors:

1) Adaptation of these techniques by the industry to their process lines.

2) Change in the Standard of Identity for Canned Salmon.

In the URD study, it was found that, for the polyphosphate to be effective in reducing curd, it had to be applied to the cut pieces before they were put into the can. Because of this requirement, it will probably be necessary to make some modification to existing process lines producing the traditional steak pack. Since the boneless/skinless products are relatively new and processing lines are just being developed, it should be a relatively easy matter to introduce a polyphosphate dip or spray into such a line.

The current Standard of Identity for Canned Salmon permits only the use of salt and edible salmon oil to be added to salmon. It will be necessary for the salmon canning industry to petition the Food and Drug Administration (FDA) to get a change in this standard. In the interim, the industry can get a temporary variance to the standard to allow a polyphosphated canned salmon product to be marketed for test purposes. For such a variance, the product will have to disclose to the FDA how much polyphosphate will be added to the product, what changes the polyphosphate undergoes during processing, and what benefits the additive confers on the finished product. Source: John C. Wekell, Utilization Research Division, NWAFC, Seattle, Wash.

NMFS Will Produce Fish Oil for U.S. Health Researchers

Scientists studying the health benefits of fish oil in the human diet will for the first time have a source of standardized test materials of guaranteed quality and composition according to the National Oceanic and Atmospheric Administration (NOAA). Until now, there has been no consistent and reliable source of test materials from fish oil or its derivatives. This has hampered research and made results between experiments difficult to compare, the Commerce Department agency said.

The test materials, consisting primarily of refined menhaden oil and concentrates of certain of its active chemical components will be produced by NOAA's National Marine Fisheries Service Charleston, S.C., laboratory in an agreement with the National Institutes of Health and the Alcohol, Drug Abuse, and Mental Health Administration. The materials will be available this year and will be used in investigations approved, and in some cases sponsored, by the two organizations.

Evidence has been accumulating over the past several years that the oil found in fish and shellfish, in particular components known as omega-3 polyunsaturated fatty acids, can have a beneficial effect on human health, especially regarding heart disease and stroke. "I'm excited about this program, and optimistic about the significance of its results," said William E. Evans, head of the National Marine Fisheries Service. "This agreement will open the way for controlled research into the role that fish oil plays in our diets, especially in prevention and treatment of cardiovascular disease, cancer, asthma, and certain kinds of arthritis."

Pacific Salmon Quality Studied

A cooperative project to document the quality changes in fresh and frozen coho salmon, *Oncorhynchus kisutch*, and pink salmon, *O. gorbuscha*, has been initiated by the NMFS Northwest and Alaska Fisheries Center's Utilization

Research Division and the Alaska Seafood Marketing Institute. The first phase of the study involved sensory and chemical measurements of quality changes during iced storage of the two species. Preliminary results showed that pink salmon can be stored in ice about 8 days without significant quality loss. However, after 10 days of iced storage the quality is affected by abnormal odor and flavor.

Coho salmon remained highly acceptable through 10 days of iced storage and showed slight changes in odor and flavor after 13 days. Significant quality change was evident after 15 days of iced storage. Samples from both species were frozen after various iced storage periods and will be thawed at 3-month intervals and compared with control samples frozen at the beginning of the study.

Five-Year Marine Mammal Cruise Program Begins

Twelve scientific observers returned to San Diego, Calif., late last year after 120 days at sea searching for schools of dolphins aboard the NOAA research vessel *David Starr Jordan* and *McArthur*. The cruises were the first in a 5-year program to monitor the abundance of stocks of dolphins in the eastern tropical Pacific, and the monitoring program is a result of an amendment to the Marine Mammal Protection Act which directed the National Marine Fisheries Service to design and carry out such a program.

The NMFS' Southwest Fisheries Center in La Jolla is responsible for carrying out the program. Ultimately, the information obtained will be used to determine if the tuna purse seine fishery in the eastern tropical Pacific has adversely affected one or more of the dolphin stocks which are associated with the schools of tuna being fished. The Secretary of Commerce is then empowered under this law to take action to modify the existing dolphin quotas for the U.S. tuna fishery to ensure that the dolphin populations are able to recover.

Cruise chief scientist Rennie S. Holt of the SWFC said that on an average day three schools of 200 dolphins each were seen from each vessel. The observers recorded how many animals they saw, the species of the animals, and where the animals were sighted. At the completion of the cruise, the scientists begin entering the data on a data base. By the end of the 5-year program when the sixth cruise is completed, scientists will have a comprehensive data base from which to determine whether the population of dolphins in the eastern tropical Pacific is increasing or decreasing.

Along with the counts of dolphins, the scientists also collected oceanographic information, such as measurements of surface temperature, salinity, and fluorescence. The scientists will use this information to determine whether the presence of dolphins is associated with a certain oceanographic environment. The oceanographic information is also being collected as part of a major NOAA ecosystem study. Scientists in this study are looking for evidence of the warm-water oscillation known widely as "El Niño."

NEFC Studying Recovery of 12-Mile Dumpsite

The NMFS Northeast Fisheries Center has completed its plans for the study of the recovery of the New York Bight's "12-Mile Dumpsite," a major site for sewage sludge disposal from New York City. Disposal of the sludge there since 1924 has altered adversely the area's benthic habitats, and has affected its shellfish, finfish, and other marine resources. Gradual phaseout of the dumpsite began in April 1986 and will cease by December 1987.

To document changes in chemistry and biota resulting from the closure, the Center is sampling 27 sites, covering all habitat types, each month until at least a year after the dumping stops. Data will be gathered on distribution, abundance, food habits, gross disease, small and medium-sized bottom-dwelling animals, organic contaminant levels in various animals, water movements, water chemistry, and sediment chemistry.

Fish samples have been examined for size and biomass estimates. Subsamples of winter flounder, red hake, and American lobsters have been examined for dietary items, and winter flounder were tagged and released. In general, invertebrates, mainly rock crabs, have dominated the catches. Groundfish (flounder and hake) were in low abundance, and, as expected, spotty catches were made of squid and butterfish.

The multidisciplinary study will monitor microbial contamination in shellfish (with FDA support) to determine changes in areas acceptable for harvesting. Rates of change in chemical burdens and changes in community structure will be used to develop a model of resource recovery.

Collaborating groups include Brookhaven National Laboratory, U.S. Environvironmental Protection Agency, University of Delaware, Food and Drug Administration, and other elements of the National Marine Fisheries Service, NOAA.

NOAA Hydrolab Goes to the Smithsonian

NOAA Hydrolab, formerly an underwater home and base of operations for marine research divers, has become a permanent exhibit at the Smithsonian Institution in Washington, D.C. Until 1985, the facility was operated by the West Indies Laboratory of Fairleigh Dickinson University in 50 feet of water off St. Croix in the Virgin Islands.

During its nearly 8 years of use, NOAA Hydrolab served as a base for nearly 200 scientific missions involving 400 scientists from 10 nations. Areas of research included studies of marine fisheries, pollution, and pharmaceuticals, as well as diving medicine, underwater instruments, etc. Resembling a huge, squat bottle, the cylindrical Hydrolab is 16 feet long and 8 feet in diameter. For

the Smithsonian exhibit, one side has been cut away to reveal the interior, with replicas of three diver-scientists depicted at work in the furnished chamber.

Aquanaut-scientists were able to live in Hydrolab and work in the surrounding waters for 7 days without returning to the surface because their body tissues were saturated with oxygen and nitrogen at the same pressure as the surrounding waters. NOAA Hydrolab divers could work full 8-9 hour days as opposed to 25-minute bottom time for scuba divers working from the surface. Cold temperatures was also less of a problem since divers could return periodically to the Hydrolab to warm up in its 75-degree chamber. A surface buoy connected by an umbilical line supplied fresh air, power, and a communications link to the surface.

Reports Elliott Finkle, director of NOAA's Underseas Research Program, "There have been larger and more luxurious subsea bases, but Hydrolab has been the real workhorse of underwater diving habitats. More hours of saturation dives were made out of Hydrolab than from all other underwater habitats combined to date."

Continued Great Lakes Flood Levels Predicted

Record high water levels in the Great Lakes coupled with warm winter in the area could result in further severe flooding of Chicago's Lake Michigan shoreline, NOAA scientists report. Frank H. Quinn, head of NOAA's Lake Hydrology Group at the Great Lakes Environmental Research Laboratory in Ann Arbor, Mich. said, "Water levels, generally, in the Great Lakes are setting records, and will through the summer. Lakes Michigan, Huron, St. Clair, and Erie are at record levels, while Ontario looks as if it will reach a record height this spring. Only Superior is below its record level."

Thus, such lakefront cities as Chicago, Milwaukee, Traverse City, Toledo, Cleveland, and Buffalo face possible flooding under certain weather conditions. "The potential for problems is much greater than it ever has been during the years we have been keeping water level records," the Commerce Department agency official said. "This is partly because there isn't much ice on the lakes this winter." He said that most of the flooding, erosion, and other damage occurs when lake water is driven against the shoreline during storms, an effect minimized when the lakes are covered with ice.

A high water level possibility was noted more than a year ago by the NOAA laboratory, and this has allowed many lakefront communities to activate flooding preparedness plans, some assisted by the Army Corps of Engineers. "The problem will not go away at the end of the stormy season in April or May," Quinn added. "Our research indicates we are likely to have high lake levels for at least the next several years."

The Great Lakes system, he noted, would take 6-10 years to return to normal levels even if precipitation, runoff, and other factors during that time were normal. "Even if we had a drought it would take Huron and Michigan three and a half years to return to the usual levels, and Lake Erie would take four years." NOAA's National Ocean Survey operates a network of water level gauges throughout the Great Lakes, while its National Weather Service provides marine forcasts for the lakes.

Winter Flounder Tagged, Studied

The National Marine Fisheries Service (NMFS) has begun tagging winter flounder (blackbacks) early this year in the New York Bight, the Northeast Fisheries Center reports. Winter flounder caught by the NMFS's research vessel *Kyma* from a 100-square-mile area centered about 10 miles offshore, as well as from the Sandy Hook-Raritan Bay complex, are being tagged. The tag is a half-inch diameter yellow plastic disc imprinted with an identification number and the return address: Sandy Hook Laboratory, Highlands, New Jersey 07732.

Data from the study will provide information on local movements, seasonal migrations, and growth rates of the species. Fishermen catching tagged winter flounder are requested to return the tag along with information on the date and location that the fish was caught, and on its length. The cooperation of fishermen will greatly aid the scientists at the NMFS's Sandy Hook Laboratory in learning more about winter flounder. For additional information contact Beth Valdes at (201)872-0200.

Stone Crab Divided Into Two Species

The stone crab, known until recently as *Menippe mercenaria* in the Caribbean and Carolinian provinces of the western North Atlantic Ocean, is divisible into two morphologically distinct populations with almost separate, narrowly overlapping ranges, NMFS researchers report. These populations have now been recognized as distinct species by A. B. Williams and D. L. Felder.

The species differ in color, carapace morphometry, and stidulatory patches on chelae of the chelipeds. *Menippe mercenaria*, the Florida stone crab, ranges from Cape Lookout, N.C., through peninsular Florida, the Bahamas, and the Greater Antilles, to the Yucatan Peninsula of Mexico, and Belize. *Menippe adina*, the Gulf stone crab, ranges from northwestern Florida around the Gulf of Mexico to Tamaulipas State, Mexico. The two species hybridize in the Apalachee Bay region of northwestern Florida.

Walleye Pollock and Its Utilization and Trade

Introduction

The annual harvest of walleye pollock, *Theragra chalcogramma*, also called Alaska pollock, currently represents the world's largest single-species fishery; catches were between 5 and 6 percent of the total world fisheries harvest in 1984 and amounted to a record high 6.0 million metric tons (t). Although walleye pollock is found throughout the North Pacific, stocks are centered principally within the exclusive economic zones of the United States and the Soviet Union. In addition, there are several pollock stocks located in the Sea of Japan. Four countries (the Soviet Union, Japan, the United States, and the Republic of Korea (ROK)) harvest over 95 percent of the world walleye pollock catch. About one-fourth of this total catch has been harvested within U.S. waters in recent years.

Walleye pollock is marketed throughout the world in various forms and the potential for expanded uses of this groundfish species is great. The most interesting commodity produced from pollock is surimi, a minced product which is used to manufacture such products as imitation crab legs, scallops, shrimps, and other analog foodstuffs. Worldwide pollock surimi production exceeded 400,000 t in 1984 and experiments are being conducted on other marine species to test their commercial viability for surimi production.

Walleye Pollock Harvests

Pollock stocks occur throughout the eastern and western North Pacific Ocean from the Sea of Japan, the Okhotsk and Bering seas, the Gulf of Alaska, and extend into waters off British Columbia. Although fishery biologists are uncertain about walleye pollock stock identification, it is generally accepted that there is a likely amount of migratory mixing among neighboring stocks in certain areas of the North Pacific—especially in the Sea of Japan.

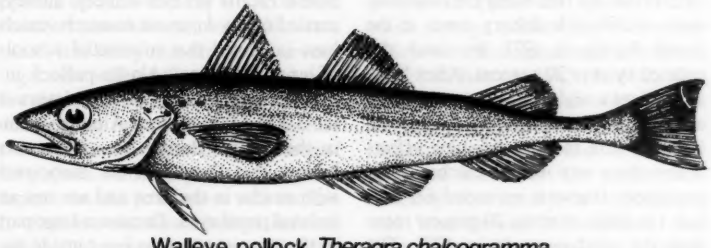
A study made in 1977 suggested that there are at least 12 major pollock stocks in the entire North Pacific. Four of these stocks are located in the Sea of Japan at: 1) Western Hokkaido; 2) northern Japan (Honshu); 3) western Japan (Honshu); and 4) Primorskiy-Korean peninsula. North of Hokkaido there are two more pollock stocks at: 5) Kuril Islands and 6) east and southern Hokkaido. In the Sea of Okhotsk, there are two stocks identified as the: 7) Sakhalin-Hokkaido and 8) northern Okhotsk stocks. Moving east from the Sea of Okhotsk, observers note the 9) Kamchatka peninsula stock.

The three remaining pollock stocks are found around North America in: 10) The eastern Bering Sea; 11) the Gulf of Alaska; and, finally, 12) waters around British Columbia. It should be noted that within these stocks observers report differing genetic characteristics that further subdivide stocks into local groups; details regarding the structure of each stock or local subgroup have not been investigated and analyzed in detail. Some fishery biologists believe that the biomass of all these pollock stocks exceeds that of any other demersal species.

Much of the walleye pollock fishery is conducted by bottom trawling, although gillnetting, longlining, and midwater trawling are also used in the fishery. The length of a mature walleye pollock is between 30 and 60 cm and the weight of an individual averages between 0.2 and 1.4 kg. Walleye pollock is harvested throughout the North Pacific wherever stocks are found, but in recent years greater harvesting efforts have been made in specific fishing areas (Fig. 1). About 75 percent of walleye pollock harvests are made in the eastern North Pacific; the other 25 percent are made west of long. 175°W, primarily in U.S. waters. Although the flesh of walleye pollock is most commonly utilized for human consumption, stocks are often adversely affected by parasites in many fishing regions. In this event, harvests are often used for fishmeal.

Ever since the 1973 El Niño phenomenon decimated the Peruvian anchovy fishery, walleye pollock has been the world's largest single-species fishery. Despite this fact, the pollock fishery is remarkably little known to the general American public, considering that a large segment of it occurs within the 200-mile fisheries zone of the United States. The reason for the lack of information probably stems from the fact that the fishery is only about 20 years old around Alaska and did not involve U.S. commercial fishery participation until recently.

Historically, the North Pacific fishery



Walleye pollock, *Theragra chalcogramma*

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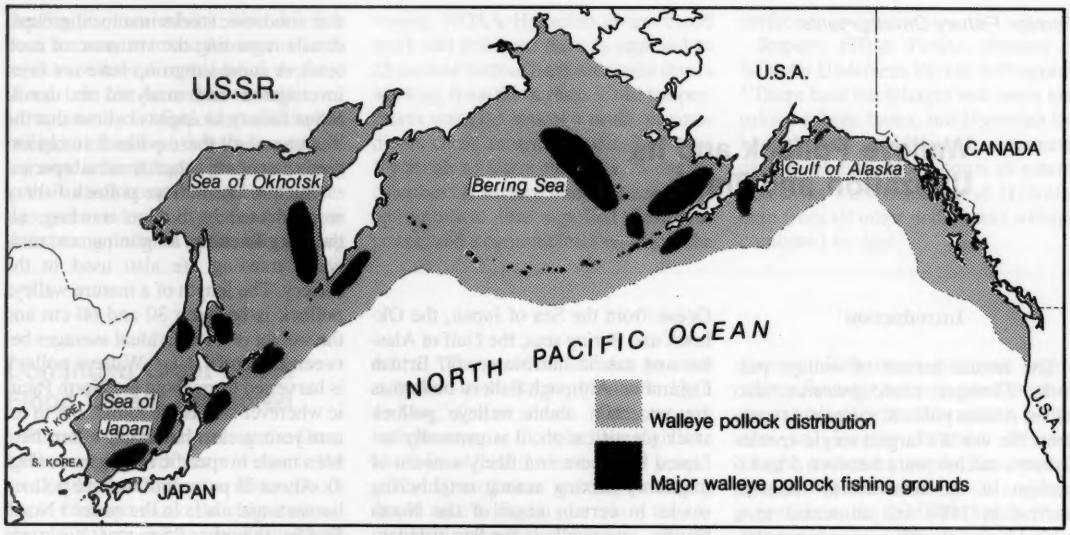

Figure 1.—Distribution and major fishing grounds for walleye pollock.

for walleye pollock was limited to the coastal waters of Japan and Korea until the late 1950's, when it underwent a rapid expansion as a distant-water fishery. Japanese operations, in particular, spread quickly up into the Sea of Okhotsk and across into the Bering Sea during the 1960's. The Japanese harvest of walleye pollock in the Bering Sea increased from 25,800 t in 1960 to over 655,800 t in 1969. At the same time, pollock fishing efforts elsewhere in the North Pacific, particularly by Soviet fishermen, also expanded. During the 1960's, annual pollock harvests increased from 465,000 t in 1961, to nearly 3.6 million tons by 1971.

The annual world catch of walleye pollock was about 5.0 million tons in 1975 (Table 1). Following the establishment of 200-mile fishery zones in the North Pacific in 1977, the catch decreased by over 20 percent. After 1980, when Japan and Korea secured catch allocations within U.S. waters and the Soviet Union increased fishing efforts within their own waters, catches again increased. Harvests exceeded 6.0 million t in 1984, or about 20 percent more than the catches made in 1975. The potential for increased harvests depends upon the size of the walleye pollock biomass, which is not known with any certainty by biologists.

Table 1.—World walleye pollock catch, by country, 1975-84.[1]

Country	Catch (1,000 t)									
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984[1]
U.S.S.R.	1,958.1	2,090.9	1,975.1	2,011.9	2,048.8	2,111.7	2,137.9	2,497.9	2.747.0	3,449.6
Japan	2,677.4	2,445.4	1,927.6	1,546.1	1,551.1	1,552.4	1,595.3	1,570.4	1,434.4	1,605.9
United States	negl.	0.2	0.3	1.8	3.1	1.4	60.7	130.4	284.5	455.1
S. Korea (ROK)	387.8	532.6	390.6	361.9	297.2	286.2	278.6	262.1	367.4	398.6
Poland	0.5	negl.	1.4	1.2	40.4	61.0	92.9	0.4		53.7
Germany (FRG)						6.0	10.3	16.1	23.7	24.4
Canada		1.3	0.9	2.4	3.4	2.2	1.1	0.9	1.0	0.7
Total[2]	5,023.9	5,070.4	4,295.9	3,925.3	3,944.0	4,020.8	4,176.8	4,478.2	5,047.3	5,986.0

[1]Sources: FAO "Yearbook of Fishery Statistics, various years; NMFS "Fisheries of the United States, 1984".

In an interesting development to the North Pacific pollock fishery, surveys carried out by Japanese research vessels have indicated that substantial schools of large adult-sized Alaska pollock inhabit the surface and midwater layers of the 3,000-4,000 m deep Aleutian basin in the central Bering Sea. Observers believe that these fish are associated with stocks in the area and are not an isolated population. Because a large part of the area in question lies outside the 200-mile zones of the United States and the Soviet Union, vessels from Japan, China, Korea (ROK), and other countries, have reportedly concentrated fishing efforts there in recent months to offset restrictions made by either the United States or the Soviet Union in their respective fishery zones.

Soviet Union

The Soviet Union currently maintains the world's largest walleye pollock fishery (Fig. 2), and harvests annually account for about one-fourth of the total Soviet fisheries catch. Soviet fishermen caught a record-high 3.4 million t in

1984, accounting for 55 percent of the world's pollock harvest. Soviet catches have increased steadily since 1978 because of expanded fishing efforts within domestic waters. Estimates on the biomass of the four pollock stocks located within the Soviet 200-mile zone are unavailable, and observers are not sure whether Soviet stocks can withstand annual harvests of over 3.0 million t on a sustained basis.

The Soviet Government, under terms of a bilateral treaty with Japan, permits Japanese fishermen to harvest pollock within the Soviet 200-mile zone. Annual pollock quotas for Japanese fishermen in the Soviet waters decreased from 290,000 to 250,000 t between 1980 and 1985, and decreased further in 1986, after the Soviet-Japanese annual agreement resulted in a quota of only 150,000 t of pollock for Japanese fishermen. Some observers have speculated that Japan may be forced to pay "cooperation fees" to the Soviets in exchange for harvesting pollock within Soviet waters in future years.

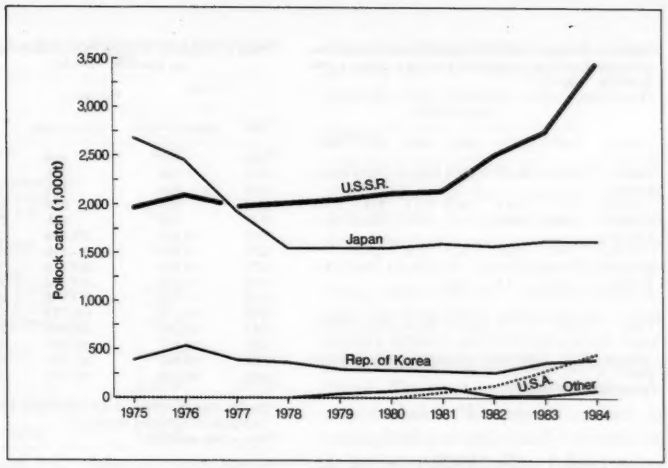

Figure 2.—World walleye pollock catch, 1975-84.

Japan

The Japanese pollock fishery was mostly limited to coastal waters until the 1960's. The fishery became more important to the Japanese after harvests of yellowfin sole in the Bering Sea greatly decreased in the early 1960's. An additional impetus to the pollock fishery occurred in 1967, when Japanese fishery technologists developed a mechanical process to manufacture pollock into a traditional Japanese seafood commodity: Surimi. Harvests by Japanese mothership and large trawlers increased greatly until reaching an apex during 1972 and 1973, when catches exceeded 3.0 million t in both years.

Japan's annual pollock harvest was once that country's largest fishery, accounting for almost one-third of the total fisheries catch. Because of the restrictions placed upon Japanese distant-water trawling after the establishment of 200-mile zones, pollock harvests decreased and the fishery now ranks second in size to the sardine fishery. Over one-half (55 percent) of the Japanese pollock catch made in 1984 was harvested within the 200-mile zones of the United States and the Soviet Union.

Japan's distant-water fishermen are permitted to harvest pollock within both the U.S. and Soviet 200-mile fishery zones under terms of bilateral agreements negotiated by the Japanese Government. As a result of these bilateral arrangements, the Japanese pollock harvest remained relatively stable between 1978 and 1984. This enabled the Japanese distant-water demersal fishing industry to weather socioeconomic disruptions caused by the establishment of 200-mile fishery zones. In addition to receiving allocations from the United States and the Soviet Union, Japanese vessels also participate in pollock joint ventures with U.S. and Soviet fishermen. These joint ventures involve the over-the-side purchase of pollock by Japanese factory trawlers from U.S. and Soviet trawlers.

Because of the interesting capacity of U.S. fishermen to harvest and process pollock, coupled with the fact that the pollock stocks within the U.S. 200-mile fisheries zone have decreased in recent years, it is likely that Japanese harvesting levels will decline during the next few years and result in a greater dependence upon imports and joint venture purchases to meet the domestic demand for pollock. Accordingly, it is likely that Japan's surimi production will slacken in relation to decreased pollock harvests unless the Japanese are able to offset this by importing greater quantities of pollock and pollock-surimi from other nations, or by developing a surimi industry utilizing other marine species, which observers believe is unlikely.

United States

Walleye pollock harvests by U.S. vessels have increased significantly in recent years. U.S. fishermen caught 455,000 t in 1984, compared with only 20 t in 1975. This sharp increase in the pollock catch can be attributed to the increase of joint-venture activities with foreign countries, especially Japan and the Republic of Korea, and increased domestic pollock landings.

Prior to 1977, pollock was harvested primarily by distant-water foreign vessels off the U.S. coast. Since 1977, however, foreign access to U.S. waters has been restricted, thus enabling U.S. fishermen to harvest increasing quantities of all commercially important groundfish species off Alaska. Meanwhile, foreign pollock harvests within U.S. waters decreased from 1.1 million t to 0.8 million t in 1985 (Table 2). The U.S. pollock catch began to increase as a result of increased joint venture arrangements with Japan and the Republic of Korea after 1981; the entire catch resulting from these joint ventures was sold over-the-side to Japanese and Korean processing vessels. U.S. fisher-

Table 2.—Foreign catch of walleye pollock within the 200-mile Exclusive Economic Zone, by country and quantity, 1980-85.[1]

Country	Catch (1,000 t) 1980	1981	1982	1983	1984	1985[2]
Japan	870.9	855.2	835.4	732.1	723.5	635.5
Korea (ROK)	141.0	154.6	196.2	217.1	218.4	174.7
Poland	59.2	93.9			55.0	32.0
Germany (FRG)	6.0	10.3	16.1	23.6	24.4	
U.S.S.R.	39.2				11.8	1.5
Taiwan	5.0	3.4	4.2			
Total	1,119.1	1,117.3	1,051.9	972.8	1,033.2	843.7

[1]Source: NMFS, "Fisheries of the United States," various years.
[2]Preliminary statistics.

Table 3.—Republic of Korea (ROK) pollock harvests, by quantity, 1970-84.[1]

Year	Harvest (t) Adjacent-water	Distant-water	Total
1970	N/A[2]	N/A	13,400
1971	N/A	N/A	71,300
1972	N/A	N/A	148,500
1973	N/A	N/A	257,000
1974	N/A	N/A	297,218
1975	4,540	327,939	332,479
1976	5,546	444,516	450,062
1977	18,584	267,715	286,299
1978	11,295	257,553	268,848
1979	11,716	217,718	229,434
1980	28,112	189,774	217,886
1981	50,283	228,353	278,636
1982	38,413	223,682	262,095
1983	29,642	337,780	367,422
1984	39,906	358,716	398,622

[1]Source: Korean Ministry of Agriculture and Fisheries, "Yearbook of Fisheries Statistics."
[2]N/A = Not available.

men landed only 10,900 t out of the 455,000 t of pollock that they harvested during 1984. In 1985, U.S. fishermen were able to increase domestic landings of pollock greatly, and over 55,000 t were landed at U.S. ports.

Within the past 5 years, U.S. companies have introduced freezer trawlers into the pollock fishery off Alaska. In 1985, some 14 U.S.-owned freezer trawlers were involved in harvesting and high-seas processing of pollock in the Gulf of Alaska and the Bering Sea. The presence of these vessels has enabled the United States to increase domestic pollock landings.

Republic of Korea

Korea has long had an active fishery for walleye pollock. Before World War II, it is estimated that Korean nationals accounted for a major part of world pollock landings. Presumable because of over-capacity within adjacent waters, Korean fishermen, in newly acquired distant-water trawlers ventured to harvest walleye pollock during the 1970's in areas that are now within Soviet or U.S. fishing zones. Between 1970 and 1975, Korean harvests increased from 13,400 to 532,000 t, and were made primarily in waters that are now under the jurisdiction of the Soviet Union. Because of the loss of access to Soviet waters after 1976, Korea sought access to the U.S. 200-mile zone for its trawlers in the eastern Bering Sea and the Gulf of Alaska. A fisheries agreement was arranged between the two countries which has since regulated Korean fishing within U.S. waters. Over 70 percent of Korea's pollock harvests have been made in U.S. waters in recent years.

Korean fishermen harvested nearly 400,000 t of walleye pollock in 1984—mostly in the eastern Bering Sea. The Koreans also maintain an "adjacent-water" fishery for pollock within the Sea of Japan, where about 30 percent of their pollock harvests are made (Table 3). During the early 1980's, Korea's pollock fishery was conducted by about 50 stern trawlers in the North Pacific. It is not known how many vessels are currently involved in the fishery.

Other Countries

Several other nations have harvested walleye pollock on a commercial basis, including Poland, the Federal Republic of Germany, and North Korea. Canadian fishermen also harvest small quantities of pollock, but their catches have never exceeded 3,500 t per year and probably will never develop beyond that level because of insufficient stocks within Canadian waters. Both Polish and West German fishermen were allowed to harvest pollock within U.S. waters in recent years, but the West Germans discontinued fishing after 1984 due to various economic reasons. Poland was prohibited from fishing in U.S. waters after martial law was declared by its government. Polish fishermen were allowed to reenter the pollock fishery in U.S. waters in 1984 after the Polish Government eased martial law restrictions.

North Korea is another significant pollock harvesting nation. Observers report that the North Koreans annually harvest somewhere between 200,000 and 300,000 t of walleye pollock either in the Sea of Japan or in the Soviet 200-mile zone, but more recent information is not available concerning North Korean pollock fishing activities. It is known that one pollock stock, known as the Primorskiy-Korean Peninsula stock, is found in North Korean waters (Fig. 3). Not much is known about this stock, although observers believe that it is probably being intensively exploited by North Korean fishermen.

China is a new entrant into the North Pacific pollock fishery. In 1985, the West Germans sold three stern factory trawlers to China. Following this purchase, the Chinese sought and received

Figure 3.—Location and migration patterns of the Primorskiy-Korean Peninsula pollock stock.

permission from U.S. authorities to fish for surplus pollock in U.S. waters during 1986. In addition, the Chinese have also established over-the-side pollock joint ventures with U.S. fishermen.

Utilization and Trade

The walleye pollock is an extremely versatile fish whose flesh is light-colored, mild-flavored, moist, and firm-textured, with a low fat content. Because the species is such an abundant resource in the North Pacific, it is most widely utilized as surimi; it is also gaining acceptance as a substitute for cod and haddock in international groundfish trade where it is marketed as individual fillets or as fish sticks and portions made from frozen fillet blocks. In addition to the surimi and block markets, pollock roe is also popular in Asian markets.

International trade in the walleye pollock is difficult to quantify and assess because few countries report pollock imports and exports in separate statistical categories. Much of the pollock trade is in the form of blocks or surimi and surimi-based products and is not recorded in trade data by species. Japan, the leading market for pollock, records its pollock imports in a basket category, but recently began recording exports of pollock and other species processed as surimi in an individual category. Trade statistics for the European Community recently began to include pollock in a separate category. Only a limited analysis of world trade in pollock commodities can therefore be done using available statistical information.

The most interesting and expanding use of walleye pollock is for the production of surimi and surimi-based commodities. Although Japan is the world's leading producer of pollock surimi and surimi-based products, the Soviet Union, the United States, and the Republic of Korea, all have fledgling surimi processing industries that presently utilize pollock as a raw material. Several other countries, among them Canada, Norway, the United Kingdom, and the Faeroe Islands, are also involved in developing surimi production using local groundfish and pelagic resources. These industries may expand in the future and intensify competition in the world surimi market.

Table 4.—Japan's estimated walleye pollock supply, 1984.[1]

Source	Amount	
	× 1,000 t	Percent[2]
Imports[3]	60.0E[4]	3.0%
Joint ventures (j/v)		
With U.S.S.R.	50.0E	2.5
With U.S.	341.0	17.0
Subtotal	391.0E	19.5
Harvests		
In U.S.S.R. zone	250.0E	12.0
In U.S. zone	723.5	35.0
Coastal/high seas	631.4E	31.0
Subtotal	1,604.9E	78.0
Supply	2,055.9E	100.0%
Exports subtracted	−30.0E	
Total supply	2,025.9E	

[1]Sources: FAO "Yearbook of Fishery Statistics," Japan Fisheries Association, and personal communications.
[2]Percentage of the total supply.
[3]Japan does not publish pollock import statistics; observers estimated Japan's 1984 pollock imports at 60,000 t.
[4]E = Estimated.

Soviet Union

Most of the Soviet pollock catch is reportedly either consumed domestically or processed into fishmeal; the Soviets also export or barter an unkown amount of pollock commodities, but trade statistics are unavailable. A portion of the Soviet pollock catch is processed into fishmeal because stocks in some fishing areas—such as in the Tatar Strait off of Sakhalin Island—are adversely affected by parasites. Because of the desire to increase earnings of hard currency, the potential for pollock commodity exports from the Soviet Union may intensify competition in the international groundfish market. The Soviet Government, however, may not wish to market pollock commodities abroad because of the great demand for food fish and fishmeal in the Soviet Union. The Soviet Government not only has a desire to increase per capita domestic fish consumption greatly by 1990, it also wishes to expand the domestic output of fishmeal for much-needed use in the agriculture industry. Besides utilizing whole and filleted pollock and fishmeal domestically, the Soviets also use pollock as a major ingredient to make an imitation sausage that is sold under the brand name "Primorskaya". The fish sausage is being produced in the Soviet far east city of Ussuriysk and is reportedly very popular with consumers.

Japan

Pollock is a popular and readily available species in the Japanese seafood diet. Besides being consumed in fresh form, the fish is used to produce a variety of products including: Dried pollock, salted pollock, pickled pollock, and cured pollock roe. But the most widely known use of pollock by Japanese consumers is in surimi end-product form[1]. The most common surimi products include: "Kamaboko", which is semicylindrical and usually steamed on a small wooden pallet; "chikuwa", a slender hollow cylindrical product which is usually roasted; "kanikama" a shellfish analog product which is crab flavored. In addition to these products, there are several other seafood analogs (such as imitation scallops, shrimp, lobster tails, etc.), as well as several food analogs, that are popular in Japan.

Observers estimate that Japan obtained about 1.4 million t or nearly 70 percent, of its apparent total pollock supply from either U.S., Soviet, or Korean sources in 1984 (Tble 4). This supply consisted of allocated harvests made by Japanese fishermen in either the U.S. or Soviet 200-mile zones, joint venture purchases from U.S. and Soviet fishermen, and from pollock imports. The remainder of the supply—650,000 t, or about 30 percent—was harvested by Japanese fishermen either within 200-miles of Japan's coast (either in the Sea of Japan or off the east coast of Hokkaido) or in the high seas (the Bering Sea "doughnut").

Most of Japan's pollock supply is converted into surimi. This fact can be deduced by comparing the total pollock supply with the total production of surimi. Table 4 illustrates Japan's apparent total supply of pollock for 1984, based upon all available sources. From this total estimated supply of pollock, Japan

[1]Most surimi is produced from minced pollock that has been washed, refined to remove impurities, and mixed with cryoprotectants to maintain essential physical properties of the product during frozen storage. As such, surimi is an intermediary product that is not consumed directly, but manufactured into a finished product for consumer use.

produced 400,000 t of surimi during 1984. Because the conversion factor from whole pollock to surimi is between 20 and 25 percent of whole pollock weight, this indicates that Japan converted between 1.6 to 2.0 million t of round-weight pollock in 1984, or almost all of the pollock harvested by Japanese fishermen (1.6 million t), in addition to the pollock that was purchased directly through joint ventures or from foreign processors (0.5 million t). The majority of the surimi produced by Japanese processors goes to the domestic market, although in recent years Japan's exports of surimi-based imitation shellfish products—mostly to the United States—has greatly increased (Table 5).

Japan purchased about 341,000 t of U.S.-harvested pollock under joint venture arrangements with Alaskan fishermen in 1984 (Table 6). This accounted for about 17 percent of Japan's pollock supply that year. In addition to joint venture arrangements with U.S. fishermen, the Japanese also purchased an estimated 50,000 t from Soviet fishermen through a joint venture in 1984. Precise details are not known about the Japanese/Soviet pollock joint venture with regard to prices received by Soviet fishermen, nor is it clear whether or not these joint-venture activities will increase in the future. It is known that the joint venture involved roe pollock purchases

With regard to direct imports of pollock, exclusive of joint venture purchases, only about 3 percent (60,000 t) of Japan's total pollock supply was augmented by imports in 1984. The reason why Japan did not obtain a more significant amount of its pollock from imports in 1984 was due to quantitative restrictions and tariffs (between 7.5 and 16.0 percent ad valorem) which the Government of Japan continued to place upon imports to protect the domestic fishing industry. During 1984, the Japanese Government controlled imports of Alaska pollock through an import quota regime known as the "98-Country Quota on Fish and Shellfish." (A number of marine species are still included in this import quota, including cod, yellowtail, mackerel, sardine, saury, scallops, and others.) This regime regulated imports of certain fish and shellfish species of concern to the domestic fishing industry by announcing semiannual quotas for several different species. A problem in the quota system was that it was impossible to determine an individual commodity's quota because all commodities were lumped together and expressed as a single figure in terms of value. After the United States complained to Japan about the import quota system, the Japanese introduced a new semiannual quota system on 15 June 1985. The new regime is unique because it removed pollock and pollock surimi from the previous quota regime and established a new "global" quota exclusively for these commodities. Unfortunately, however, it is still not possible to distinquish between individual quotas for these two commodities as they are still combined under a single figure in terms of quantity. In addition, the quota is divided among Japanese fishermen, processors, and importers, with the fishermen—who have little interest in importing processed pollock—receiving the largest share (over 90 percent) of the import quota (Table 7). The fishermen's share is used predominately for joint-venture purchases.

The Japanese produce surimi both at sea in factory vessels and at land-based processing plants. Of the 400,000 t of frozen surimi manufactured by Japanese processors in 1984, about 220-225,000 t was produced "at sea" on large surimi processing vessels, while about 185,000 t was produced at land-based processing plants. Top grade factory-vessel pollock surimi sold for about $0.79 a pound in Japan in 1984, while land-based surimi sold for about $0.44 a pound. Land-based surimi from other species, notably croaker, sells for almost twice as much as sea-based pollock surimi (between $1.40-$1.50 a pound). Because the harvest and availability of croaker

Table 5.—Japanese exports of surimi-based imitation crab legs (kanikama), by quantity and destination, 1982-85.[1]

Destination	Exports (t) 1982	1983	1984	1985
United States	6,749	13,823	26,756	30,900
Australia	1,751	1,580	1,641	N/A[2]
United Kingdom	348	2,139	1,602	N/A
Canada	26	210	778	N/A
New Zealand	114	309	428	N/A
Netherlands	117	241	269	N/A
Belgium	43	157	216	N/A
Other	182	369	772	N/A
Total	9,330	18,828	32,462	38,987

[1]Source: NMFS Foreign Fishery Information Releases, various issues.
[2]N/A = Not yet available.

Table 6.—Japan's joint venture pollock purchases from U.S. and Soviet fishermen, 1981-85.

Year	J/v purchases (1,000 t) From U.S.	From U.S.S.R.	Total
1981	11	50E	66E
1982	66	50E	116E
1983	212	50E	262E
1984	341	50E	391E
1985	437	50E	487E

[1]The Japan-Soviet joint venture quota between 1981-85 was 65,000 tons per year, but observers do not believe that the quota was annually attained.
[2]E = Estimated.

Table 7.—Japan's pollock and pollock-surimi import quota for the 1985 fiscal year (April 1985 to March 1986),[1] in metric tons.

Recipient/Import commodity	4/85-9/85	10/85-3/86
Fishermen's quota		
Japan Deep Sea Trawlers Association (Joint venture pollock for surimi)	230,000	300,000
Japan Fisheries Association (Joint venture pollock not for surimi)	8,000	7,000
Japan Shore Surimi Manufacturer's Assn. (U.S. processed surimi only)	10,000	10,000
Subtotal	248,000	317,000
User's quota		
Zensui Kakoren (National Federation of Fish Processors) (Frozen pollock from North Korea)	2,500	5,000
Zen Chinren (National Federation of Delicacy Fish Manufacturers) (Frozen pollock from North Korea	2,500	1,000
Zen Kyuhan (Japan School Lunch Federation) Frozen pollock from North Korea)	500	1,000
Zen Kama (All Japan Federation of Kamaboko Manufacturers Cooperative Assns.) (Global surimi)	1,500	1,000
Subtotal	7,000	8,000
Trader's quota		
Global quota on fresh pollock for factory ship processing (Soviet joint venture for roe pollock	0	65,000
Individual Traders (Pollock from U.S.S.R. and South Korea)	15,000	10,000
Subtotal	15,000	75,000
Grand total	270,000	400,000

[1]Japan's fiscal year is from April through March every year. The Alaska pollock and pollock-surimi quota is allocated biannually, the first allocation covering April through September and the second covering October through March. Source: Regional Fisheries Attache, U.S. Embassy, Tokyo.

species is far less than the pollock resource, it is doubtful that croaker can supplant the demand for pollock. However, Japan has a large sardine resource which can possibly be produced into surimi with the present Japanese surimi technology. Observers doubt that sardine surimi can be produced economically along the same lines as pollock because it is an oilier fish with a lower protein percentage in its meat, and the surimi that has been produced is of a darker color than pollock surimi and may prove unacceptable to consumers.

Concerns about decreased supplies of pollock from the U.S. and Soviet 200-mile zones have resulted in Japanese companies increasing efforts to seek other sources of groundfish to process into surimi. For example, Nippon Suisan[2] (Nissui) came to an agreement last year with the Government of the Faeroe Islands to provide surimi technology to the Faeroese fishing industry. The Faeroese will produce surimi at sea aboard the 3,800 t vessel *Lesatender* employing technology supplied by Nissui. The surimi produced by the vessel, using local stocks of blue whiting, will be forwarded to land-based processors on the Faeroes who will then manufacture imitation crab legs (kanikama), reportedly for export to countries in the European Community. A U.K.-based subsidiary of the Japanese company, Kibun Ltd., is building a $4.2 million surimi processing plant in Lanarkshire, Scotland. The plant will be the first of its type in Europe to supply the European surimi market, which observers expect to double in the next 3-5 years from the current estimated annual turnover of $14 million (wholesale value). The company's operations will begin by importing raw pollock surimi for imitation shellfish processing. At a later date, Kibun hopes to produce raw surimi from blue whiting harvested by U.K. fishermen. Observers note that an estimated 5-million t blue whiting stock is found in waters west of the British Isles.

In addition to looking toward the North Atlantic for surimi sources, the Japanese are looking toward the South Pacific. A subsidiary of the world's largest seafood company, Taiyo, was last year granted a 20,000 t allocation of hoki, *Macruronus novaezelandiae*, within New Zealand's 200-mile zone and will conduct a test production of hoki surimi during June 1986. Meanwhile, the Japan Marine Resource Research Center (JAMARC), a quasi-governmental nonprofit organization, was to charter a trawler owned by Nippon Suisan to conduct experimental surimi processing using jack mackerel, *Trachurus murphyi*, stocks harvested off Chile (but outside the Chilean 200-mile zone) during July 1986.

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

United States

Very little of the pollock harvested by U.S. fishermen ends up on the world commodity market. Because pollock has been, until recently, an underutilized species, U.S. fishermen and producers' organizations are now increasing their knowledge of its handling and marketing. The United States has only just begun to explore the possibilities for effective pollock utilization and trade. Virtually all the pollock used for consumption in the United States is in block form that has been supplied by foreign processors. Perhaps this is due to the fact that, unlike other forms of pollock-based products, blocks are not subject to ad valorem duties. Also, transport costs for blocks are considerably lower than for other pollock-based products. U.S. imports of pollock blocks have remained steady over the past 5 years, averaging about 31,000 t annually. In 1984, the United States imported 31,500 t of blocks (over 10 pounds), with 18,900 t coming from the Republic of Korea alone. U.S. imports of pollock-based products from Japan are comprised mostly of surimi. Although only a small fraction (less than 5 percent) of the Alaska pollock caught by Japan is exported to the United States, its value is quite high because it is in surimi form. Of the 35,800 t of surimi exported by Japan in 1984, 27,100 t, valued at $84.5 million, went to the United States. The United States presently has fledgling surimi processing industries, and the outlook for future surimi production is favorable. Potential for domestic production of surimi represents a viable outlet for increased U.S. harvests of pollock. Meanwhile, Japanese companies such as Taiyo, Nichiro, Marubeni, and Nippon Suisan have invested in land-based surimi plants in the United States. In light of the increasing harvests and greater access to surimi technology, the United States appears to be moving toward developing its own place in the world market for pollock products.

Republic of Korea

Pollock has been described as a "traditional" item in the Korean seafood diet. Its availability to Korean consumers has increased since the 1960's, mostly because Korean fishermen have developed distant-water fisheries for pollock. During the 1960's, before Korean trawlers began distant-water pollock fishing near the Kamchatka peninsula and in the eastern Bering Sea, Korean fishermen reported average annual pollock harvests of only 21,000 t. After acquiring distant-water trawlers and fishing expertise in the 1970's, the annual Korean harvest of pollock increased to more than 235,000 t—or more than 10 times annual average harvests during the 1960's.

Korea obtains its pollock supply from three sources: Harvests by domestic fishermen, joint-venture purchases from U.S. fishermen, and imports. From this supply, Korean companies have developed both domestic and export markets for pollock. The domestic market is divided into a market for consumers and a market for the Korean military. It is not known how large these two "submarkets" are in relation to one another, but observers believe that the two markets combined account for about two-thirds of the Korean pollock supply. The other one-third of Korea's pollock supply is exported—primarily to the United States.

Korean companies export pollock to the United States, Japan, and Europe. The most important export market is the United States. In 1985, Korea exported over 18,000 t, valued at $22.7 million, of frozen pollock fillets in block form to the United States. This export represents about one-third of the allocated pollock which Korean fishermen received in the U.S. 200-mile zone during 1985, after a conversion factor from processed to round weight is calculated. Korea is the leading supplier of frozen pollock blocks to the United States, accounting for about two-thirds of U.S.

Table 8.—U.S. imports of pollock blocks by quantity (t) and value (US$1,000), 1980-85.[1]

Country	Pollock imports					
	1980	1981	1982	1983	1984	1985
Korea (ROK)						
Quantity	15,206	14,876	14,297	21,899	18,889	18,111
Value	20,182	23,495	20,387	27,374	24,321	22,741
Japan						
Quantity	1,720	725	858	1,756	811	1,066
Value	2,382	1,220	844	2,319	1,134	1,272
Poland						
Quantity	4,672	6,165	4,281	311		7,557
Value	6,529	9,801	7,060	367		9,120
China						
Quantity			36	36	247	367
Value			54	35	338	458
Taiwan						
Quantity						186
Value						230
Germany (FRG)						
Quantity			20	320	83	
Value			31	422	111	
U.S.S.R.						
Quantity	129	59	52			
Value	114	33	81			
Hong Kong						
Quantity	73					
Value	98					
Grand total						
Quantity	21,800	21,825	19,271	24,322	20,030	27,287
Value	29,305	34,549	28,457	30,517	25,904	33,822

[1]Source: U.S. Department of Commerce, Bureau of the Census.

Table 9.—European Community (EC) whole, fresh and frozen, pollock imports, by amount (t) and value (1,000 ECU[1]), 1983 and 1984.

Commodity by country	Imports		Commodity by country	Imports	
	Amt.	Value		Amt.	Value
Whole fresh			Whole fresh		
France	465	709	France	720	1,205
U.K.	100	78	Belg.-Lux.	63	73
Netherl.	33	24	U.K.	34	30
Belg.-Lux.	9	15	Netherl.	20	12
Germ. (FRG)	1	2	Germ. (FRG)	19	15
Denmark	1	1	Italy	8	17
	—	—	Greece	2	7
Total, EC	609	829	Denmark	1	1
			Ireland	1	
Whole frozen				—	—
France	373	310	Total, EC	868	1,360
U.K.	131	55			
Germ. (FRG)	32	23	Whole frozen		
Ireland	30	23	France	72	123
Greece	44	52	Italy	69	90
Italy	25	45	Belg.-Lux.	24	19
Belg.-Lux.	17	13	U.K.	17	3
	—	—	Germ. (FRG)	3	3
Total, EC	652	505	Netherl.	1	1
			Ireland	1	
				—	—
			Total, EC	187	258

[1]ECU = European Currency Unit. The average value of 1 ECU equaled $0.89 in 1983 and $0.78 in 1984.

pollock block imports in 1985 (Table 8). Korea's share of the U.S. block import market has fluctuated in recent years depending upon Korean frozen block production and the supplies of pollock blocks that U.S. importers obtain from other sources such as Poland.

The expanding Korean surimi industry has already become a competition concern for Japanese surimi processors. Although Japan imported only 3,000 t of Korean-produced pollock surimi in 1984, the Korean surimi was valued at $1,220 per ton, compared with $1,625-$1,710 per ton for surimi produced in Japan. The Hokkaido-based surimi industry requested that the Japan Fisheries Agency establish import regulations for the Korean-origin surimi, since there was no such category included in the 1984 Japanese import quota of $40 million worth of Korean fishery products. The following year, the Japanese Government introduced the so-called "Global Pollock and Pollock-Product Import Quota", which established a separate import quota regime for pollock and pollock-surimi. This quota system allows the Japanese to better control imports of pollock and pollock-surimi products from Korean processors.

The Koreans intended to import at-sea surimi processing technology from a Japanese company, Mikasa Boeki, and utilize that technology on three factory trawlers which they hoped to operate in the U.S. 200-mile zone. Korea currently employs three factory vessels with a total annual production of 13,000-15,000 t of raw surimi. The addition of the three new vessels will increase Korea's annual surimi production capability to 30,000 t. It is expected that the Koreans will process their increased surimi output into imitation shellfish products for the domestic and export markets. Observers believe that the Koreans will also seek to export greater amounts of raw surimi to the Japanese market while, at the same time, trying to increase exports of imitation shellfish products to the United States.

Other Countries

Although the vast majority of the pollock harvested in the North Pacific is destined for Asian and Soviet consumers, several European countries have recently increased their use of pollock products. This increased use of pollock products has been stimulated by decreased supplies of groundfish, especially cod, to European processors. The European Community (EC) temporarily suspended tariffs for frozen fillets and minced blocks (surimi) of pollock from 18 December 1985 to 28 February 1986. Both commodities are normally assessed an import duty of 15 percent ad valorem, but the EC temporarily suspended tariffs for 4,500 t of imported product. The EC apportioned this quota to three EC-member countries: The Federal Republic of Germany (2,400 t); France (1,100 t); and the United Kingdom (1,000 t). It is not known which countries were supplying the Europeans with pollock during 1983 and 1984, because EC import statistics do not provide the source of the imports (Table 9).

Sources of information on the pollock include: FAO Fish. Tech. Pap. 266, "The Fish Resources of the Northwest Pacific"; Alaska Fisheries Development Foundation, Inc., "Alaska Pollock: Resources, Fisheries, Products and Markets"; NMFS Southeast Region, "Market Trends and Outlook for Surimi-based Foods", by John Vondruska; Alaska Sea Grant Rep. 83-2, "Proceedings of the International Seafood Trade Conference"; Arthur D. Little, Inc., "The Development of a Bottomfish Industry: Strategies for the State of Alaska"; Regional Fisheries Attache, U.S. Embassy, Tokyo; various Japanese and U.S. press reports and personal communications. Special thanks to Paul Niemeier and Michelle Miller, of the NMFS Foreign Fisheries Analysis Branch, for their assistance.

European and American Surimi Developments

Introduction

Japan is the major world producer of surimi and surimi-based foods. Japanese production of surimi-based foods totaled over 980,000 metric tons (t) in 1985,[1] more than 95 percent of the world total. The Japanese have been producing surimi for centuries, but their surimi production expanded sharply in the 1950's and 1960's as a result of several important innovations, especially at-sea production and freezing, which enabled fishermen to use the huge walleye, or Alaska, pollock, *Theragra chalcogramma*, resource to produce high quality surimi.[2]

[1]This amount includes about 420,000 t of actual surimi and 570,000 t of various additives.
[2]The article beginning on page 61 discusses the walleye pollock resource and its use and trade.

High-seas processing enabled the Japanese to process the pollock immediately after catching it, a key factor as pollock deteriorates rapidly after it is caught. Japanese production has declined, however, since the early 1980's because of reduced access to walleye pollock within U.S. and Soviet 200-mile zones, higher prices, and expanding consumption of other foods as part of the increasing affluence of Japanese consumers.

Surimi began to interest international traders when Japan developed the technology in the early 1970's to produce analog products from frozen surimi. Until then surimi was primarily used to produce kamaboko which was almost entirely consumed in Japan's domestic market. With the development of these analog products, which are mostly imitations of high-valued shellfish, Japan has made significant inroads in developing a market for surimi products in the United States and various European countries.

Most of the surimi is marketed as various forms of crab, but smaller quantities are marketed as shrimp and scallops. Japanese businessmen believe that surimi can eventually be used to produce analog products of many other seafoods. Japanese sales of analog products have helped offset reduced sales of other surimi product lines, but accounted for only about 7 percent of total Japanese production in 1985.

U.S. Import Trends

Precise data on the value of U.S. surimi imports are not available, but the NMFS Foreign Fisheries Analysis Branch estimates that these imports in 1985 were about $150 million, making surimi one of the major U.S. fishery import products. Many other countries besides Japan have now begun, or are considering developing, their own surimi industries to replace imports from Japan and other countries.

U.S. import trends are difficult to follow because, until 1985, there was no separate U.S. tariff category for surimi. Current U.S. surimi import categories do not cover all the surimi and surimi-based products currently being imported into the United States. The Foreign Fisheries Analysis Branch estimates that less than half of the surimi and surimi-based products being imported by the United States is currently reflected in U.S. import statistics (Tables 1 and 2). Data available from Japanese sources, however, indicates that the United States imported 36,900 t of surimi in 1985, nearly a 25 percent increase over the 30,000 t imported in 1984.[3] Small shipments were received from eighteen

Table 1.—Recent U.S. surimi imports[1].

	Volume (t)			Value (US$1,000)		
	Jan.-June		Jan.-Dec.	Jan.-June		Jan.-Dec.
Country	1985	1986	1985	1985	1986	1985
Japan[2]	5,357.1	8,403.5	15,000.0	16,819.0	29,773.3	47,348.0
Spain	71.0	38.0	130.6	136.3	105.9	291.0
Canada	22.1	31.8	47.2	95.1	124.5	193.7
Hong Kong	29.2	25.1	32.6	127.8	93.3	154.5
Korea (ROK)	4.1	225.7	28.8	14.1	707.5	73.3
Chile	8.2		9.7	25.4		28.7
Thailand	3.0		3.0	9.8		9.8
Australia	2.4		2.6	10.5		10.5
Switzerland	1.0		2.2	3.7		8.4
Norway		2.5	1.5		3.1	11.1
Denmark	1.3		1.3	2.9		2.9
Taiwan	1.0	10.9	1.3	6.3	42.4	7.4
United Kingdom	1.2	1.0	1.2	2.5	11.2	2.5
Israel			1.1			4.5
Philippines	0.2	4.2	0.7	1.2	6.6	3.5
India	0.5		0.5	1.5		1.5
China	0.5		0.5	4.9		4.9
France	0.2	0.3	0.3	2.3	2.7	3.3
Netherlands		1.0			3.5	
Total[3]	5,503.2	8,744.4[4]	15,265.3	17,263.4	30,873.9[4]	48,160.5

[1]Due to the problems associated with introducing a new tariff category, these statistics represent less than half the surimi and surimi-based foods actually imported. They do, however, give a general indication of the level of activity in various countries. Source: U.S. Bureau of the Census.
[2]Japanese sources indicate that about twice as much surimi is exported to the United States as was reported by the U.S. Census Bureau. Japan reported exports of surimi and surimi-based analogs of about 36,900 t in 1985. Total Japanese shipments probably totaled about $150 million in 1985.
[3]Totals may not agree due to rounding.
[4]Japanese data show a decline in shipments to the United States during the first 6 months of 1986. The increase shown by U.S. statistics may simply reflect the gradual refinement of data. Exchange rate fluctuations may have also been a factor.

Table 2.—U.S. price of imported surimi, 1985-86, in U.S. dollars/kg.[1]

	Jan.-June		Jan.-Dec.
Country	1985	1986	1985
Japan	$3.14	$3.54	$3.16
Spain	1.92	2.79	2.23
Canada	4.30	3.91	4.10
Hong Kong	4.38	3.72	4.74
South Korea (ROK)	3.44	3.13	2.55
Chile	3.10	NA[2]	2.96

[1]Source: U.S. Bureau of the Census.
[2]NA = Not applicable.

other countries, principally Spain, Canada, Hong Kong (a transshipment point), South Korea (ROK), and Chile (Table 1). U.S. imports consist primarily of imitation shellfish, mostly crab analog products. Imports from Japan in 1985 consisted of 32,100 t of shellfish analog products and 4,800 t of surimi blocks.

U.S. Developments

Most observers believe that the U.S. market for surimi and surimi-based foods will significantly expand in coming years. Observers estimate the U.S. market doubled annually between 1981 and 1984. The market will probably continue to expand for the rest of the decade, although at a slower rate. One industry report suggests that by 1990, the U.S. market could require as much as 435,000 t of crab analog products alone. Expansion to this level may require the utilization of other species besides Alaska pollock, which is currently the primary raw material for surimi production.

U.S. companies hope to produce an increasing proportion of that projected total domestically. U.S. companies are planning both shore-based and at-sea surimi projects to replace imports from Japan. Three U.S. companies, all with Japanese participation, are now beginning to produce surimi domestically using shore-based plants for processing from Alaska pollock.[3] At least two U.S. fishing companies are outfitting vessels for high-seas production, and additional companies are planning equity joint ventures with South Korean companies for high-seas production. Another company plans to evaluate menhaden surimi in a pilot project during 1986-87.

Most of the initial production will be marketed domestically, but company officials also hope to export to Japan. There has been considerable discussion in the United States on how to label and market surimi-based foods. Virtually all analog products must be labeled as imitations to comply with a 1985 Food and Drug Administration regulation promulgated under a 1938 law. Crab analogs appear and taste more or less like their natural counterparts, but they have achieved a lower-priced market niche.

[3]Japanese export data indicate that Japan began exporting to the United States in 1978 when about 400 t was shipped. Exports began a spectacular increase in 1982 when over 6,700 t was exported to the United States.

Price Shifts

According to U.S. data, imports of imitation shellfish from Japan averaged $3.54/kg (f.o.b. Japan) in the first 6 months of 1986 (Table 2), 13 percent higher than a year earlier. The Japanese yen price of the intermediate raw material, top grade walleye pollock surimi blocks, also rose about 13 percent at the Tokyo Central Wholesale Market, but this has meant a 60 percent rise in the U.S. dollar price to an average of $2.86/kg in January-June 1986 because of the falling value of the U.S. dollar. U.S. industry sources report paying the higher price for Japanese surimi. Corresponding increases in U.S. dollar prices of Japanese imitation shellfish, however, appear to have been delayed, absorbed, or offset via cost-reducing changes in production, such as shifts to lower priced (non-Japanese) surimi. It is likely that price-cost considerations and the decreased supply of walleye pollock available to Japanese processors helped reduce U.S. imports of Japanese analog shellfish in 1986.

U.S. import data suggest that 1985-86 price levels and directions in some of the other supplying countries may have differed from those in Japan. Apart from possible data problems, any actual differences for prices expressed in U.S. dollars in such countries could be attributed to many factors relating to species used, production, marketing, and exchange rates. Many new companies which have entered the industry are perfecting production and marketing practices. In some cases the relatively high prices reported for surimi products, especially Canadian prices, may reflect additional processing of the intermediate raw material imported from Japan.

Country Developments

Most developments in the surimi industry have centered in Japan. Various groups in other regions have now begun to experiment with, or actually produce, surimi, both for their domestic market and to export. Some of the most important developments elsewhere in the world are reported here.

Western Europe and Canada

Both European and Canadian interest in surimi is a recent phenomena and is due both to the great commercial success of surimi-derived analogs (crab sticks, scallops, etc.) produced in Japan and for the need to develop new fisheries utilizing abundant stocks of underutilized species; this would reduce pressure on traditionally fished groundfish and pelagic stocks. During the past 4 or 5 years, a number of European fishery laboratories have conducted small-scale testing on a variety of local species to identify potential sources of surimi from European waters.

By far, the most successfully tested species has been blue whiting, *Micromesistius poutassou*, which first attracted the interest of the Nippon Suisan company of Japan in the late 1970's when the firm conducted some inconclusive tests on blue whiting in Scotland. A number of small pilot production plants were built in 1985 and 1986, and Europe's first production and processing plants recently opened in the Faeroe Islands and Scotland, with Japanese help. European industry interest, however, is still focused on determining the potential for species found locally, and consumer needs will have to be met by imports for the next few years.

Research carried on in Canada has been basically limited to testing local North Atlantic and Pacific stocks for possible use in surimi production. There appears to be no active research underway by any Canadian universities, but the Canadian Department of Fisheries and Oceans (DFO) and several private firms have expressed interest in producing seafood analogs and are conducting their own testing and marketing research. Two production and processing firms are currently producing seafood analogs on a small-scale basis.

The Faeroe Islands

Faeroese surimi testing, production, and processing has been the most suc-

cessful in Europe so far. Technologists from the Nippon Suisan Company[4] (Nissui) of Japan are working with businessmen from the Faeroese company Blue North, Ltd., to produce surimi aboard the freezer trawler, *Lasetender*, using blue whiting. Preliminary tests by Nippon Suisan suggest that surimi made from blue whiting is superior to that of Alaska pollock. The blue whiting biomass is estimated at 2-3 million t and huge schools of blue whiting spawn off the southwestern coast of the Faeroe Islands from January to May of each year. The catch will be processed into imitation crab ("Blue Sticks", "Blue Flakes", and "Blue Lops") on board the *Lasetender* for export to the European Community.

United Kingdom

Europe's second full-scale surimi processing facility began operations in Lanark, Scotland, in July 1986. The plant, opened with Japan's Kibun Group, is using walleye pollock caught by Japanese trawlers in the North Pacific to produce "Crabsticks" (30 sticks in a vacuum pouch), "SeaSticks" (a smaller crab stock designed for the catering trade), and "Oriental Parcels" (whitefish, shrimp, and vegetables in a pasta shell) for sale to British retail outlets. Kibun is importing several other products ("Prawnies" and "Seafood Choice") from their processing plants in Japan; ultimately these surimi products may be produced at their new factory in Scotland. Kibun plans to launch a major promotional program in the United Kingdom to stimulate consumer buying. If production can be sustained, the company plans to process blue whiting, possibly starting in 1988.

Norway

The Norwegians have focused on the possibility of producing surimi from capelin, *Mallotus villosus*; herring, *Clupea harengus*; mackerel, *Scomber scombrus*; blue whiting, and a few other species. The Government of Norway granted Fideco A/S of Tromso an export license to sell surimi-based meat and fish analogs produced from capelin and herring in 1985. If the experiment is successful, the company plans to build a production facility in Finnmark, Norway. Fideco A/S plans to market its product in the United States.

Iceland

An experimental effort to manufacture surimi in a freezing plant at Rif, on the western Snaefellsnes Peninsula, was started in mid-1985. Experiments are being conducted by the Icelandic Fisheries Laboratories in cooperation with the Coldwater Seafood Corporation and the Icelandic Freezing Plants Corporation. The plant is using trimmings from filleting lines—mostly Atlantic cod, *Gadus morhua*, and small saithe, *Pollachus virens*. Future testing will include silver smelt, *Argentina silus*, and blue herring. The Samband Corporation is also conducting experimental work with surimi.

Denmark

The Danish Fisheries Technological Laboratory at Lyngby has experimented with surimi production from Norway pout, *Trisopterus esmarkii*, and sand eel, *Ammodytes* spp. Earlier experiments on cod produced poor results and discouraged the industry from becoming involved in surimi production.

Sweden and Ireland

Swedish technologists have concentrated on examining ways to use cod, cod trimmings, and herring as raw materials for surimi. The work is still in the experimental stages.

An Irish fisherman has ordered a new freezer stern trawler built in Norway to process blue whiting and silver smelt into minced fish. The vessel is expected to produce about 40 t of minced fish per day when it is completed in October 1987 and press reports indicate that the product will be used to make surimi.

Canada

The Terra Nova Fishery Co., Ltd., of Clarenville, Newfoundland, set up a surimi production plant in 1984 using Japanese processing equipment supplied by Bibun, Inc. The plant is currently producing surimi using Atlantic cod stocks and has begun commercial processing of "crab stick" products. Ocean Delights, Inc., of Vancouver, British Columbia, is also presently producing "crab sticks" on a limited scale using surimi imported from Japan. The DFO's Freshwater Institute in Winnipeg, Manitoba, is conducting research to determine the suitability of freshwater whitefish and tullibee in surimi manufacture.

Latin America

Chile

A Chilean company is producing surimi at a small plant located at Los Rojas along the country's southern coast. The company is using hake, probably *Merluccius gayi*, although one report suggested that the company was also experimenting with mackerel. Most of the production is marketed domestically, but 10 t was shipped to the United States in 1985, the first such shipment from Latin America. The Japanese Marine Fishery Resource Research Center (JAMARC) has experimented with Chilean jack mackerel, *Trachurus murphyi*, as a raw material for surimi. The utilization of high-oil content pelagic species is technically possible, but involves higher costs to remove the oil. Nippon Suisan, using the results of the JAMARC research, is currently conducting high-seas surimi production utilizing the jack mackerel being taken off Chile. The company plans to produce 3 t of surimi per day and hopes to have the product on the Japanese market by October 1986.

Mexico

Unconfirmed reports indicate that a Japanese company, Suzuhiro Kamaboko Gogyo, plans to build a small pilot surimi plant near the Pacific port of Mazatlan. The plant's estimated annual production would be about 350 t. Productos Pesqueros Mexicanos (PPM), the state fishing company, has previously marketed a minced fish product called "Pepepez," a product requiring some of the same processes as surimi. PPM is not currently producing Pepepez, but it plans to eventually resume production when a new plant is completed. Government officials are cur-

[4]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

rently studying the possibility of producing surimi.

Peru

Several Peruvian companies have expressed an interest in surimi. The Instituto Tecnologico Pesquero (ITP) in Callao has done considerable work on surimi and fish paste products. ITP is currently working with the Empresa Publica de Servicios Pesqueros (EPSEP) to market fish hamburgers made from sardines. Peru's state fishmeal company, Pesca Peru, operates an experimental marine beef plant and plans to build a larger plant. Much of the machinery and processing procedures to produce marine beef and surimi are similar. Some Peruvian observers believe that Pesca Peru should redirect its efforts to surimi which may prove more commercially successful. Any major Peruvian entrance into the surimi industry, however, will probably be delayed until the economics of utilizing pelagic species has been established.

Argentina

The Latin American country with the greatest potential for surimi production is Argentina. The substantial demersal resources of hake and other species off the southern coast could provide Argentina with enough raw material to support a major surimi industry. The country's Instituto Nacional de Desarollo Pesquero (INIDEP) has reportedly done some research on surimi, and several Argentine companies have contacted Japanese companies concerning surimi. The development of a significant surimi industry, however, is probably several years off. Many of the country's major fishing companies are badly in debt. Fluctuations in squid and shrimp fisheries, the inability of Argentine fishermen to operate off the Falklands, and competition with distant-water fishermen operating in the South Atlantic have all hurt the country's fishing industry. Few Argentine companies currently have the capital to finance the production and marketing of a major new product. Some Argentine companies, however, are already producing minced fish. The United States imported about 300 t of minced fish blocks from Argentina in 1985.

Uruguay

Like neighboring Argentina, there are no known Uruguayan surimi projects, but Bero, S.A., a fish processing company is looking for a partner to launch a surimi project. Uruguayan companies already produce minced fish. The U.S. imported over 500 t of minced fish blocks from Uruguay in 1985. (Source: IFR-86/52.)

The Latin American Scallop Fisheries, 1980-86

Introduction

The development of a major scallop fishery in Peru made Latin America the largest exporter of scallops to the U.S. market in 1985. Latin American shipments totaled 5,500 metric tons (t) valued at $24 million, and scallops have become the fourth most important, Latin American fishery export to the United States. More than 10 species are harvested (Table 1), though only two contribute greatly to the exports, the Peruvian and Pacific calico scallops.

Development of the fishery and exports are based on events in two countries, Peru and Panama. Most observers believe that the rapid development of the Peruvian fishery was linked to the 1982-83 El Niño event. In 1986, Peruvian catches declined, but Panama began to report significant scallop exports. Officials in both countries are unsure of the long-term trend. Peruvian officials closed the fishery for most of 1986, except for some limited artisanal fishing. Panamanian officials have been studying possible management measures.

Export Trends

Latin American scallop exports to the United States were negligible in 1982. But as a result of climatic changes off Peru, scallops flourished, harvests increased, and shipments expanded to

Table 1.—Latin American scallop species harvested.

Country	Species harvested[1] Scientific name	English name	Local Spanish name	Average size (cm)
Argentina	*Argopecten tehuelchus*	Tehuelche	Pecten tehuelche	7.5
	Chlamys felipponei	Felippone	Felipone	7.4
	C. lischkei	Lischke's	Patria[2]	7.3[3]
	Pecten patagonicus	Patagonian	Patagonico	8.0
Brazil	N.A.		Vieiras	N.A
Chile	*A. purpuratus*	Peruvian calico	Ostion del norte	7.0
	C. lischkei	Lischke's	Ostion de las canales/concha	7.0[3]
	P. patagonicus	Patagonian	Patagonian/ostion de Magallanes	8.0
Panama	*A. circularis*	Pacific calico	Peine volador/conchuela	6.0
Peru	*A. purpuratus*	Peruvian calico	Concha de albanico/escalope	7.0

[1]Small quantities of several other species are also taken.
[2]Also vieira patria.
[3]It is now known why the average size of this species is different off Argentina than Chile.

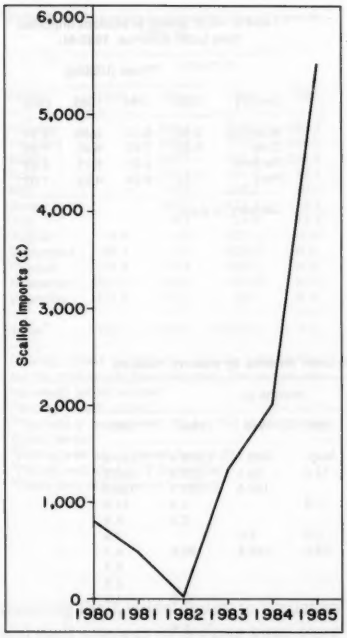

Figure 1.—U.S. scallop imports from Latin America, 1980-85.

Table 2.—U.S. fishery import values, by product, 1985, in millions of U.S. dollars.

Product	Import values: Latin America	Import values: World
Shrimp	$766.1	$1,154.0
Lobster	128.5	471.3
Tuna	76.7	425.3
Cod	Negl.	419.1
Scallops	24.0	147.1

Table 3.—U.S. scallop imports from Latin America, January-June, 1985-86.

Country	Jan.-June imports (t): 1985	1986
Panama	1.4	1,705.5
Peru	2,365.6	1,189.2
Chile	102.0	161.6
Mexico	1.0	73.4
Ecuador	8.9	18.7
Costa Rica	3.2	6.0
Honduras	1.0	4.6
Turks and Caicos		3.4
Belize		1.3
Bolivia		1.0
Argentina	31.7	0.9
Venezuela	1.9	0.7
Brazil	0.1	
Total[1]	2,516.8	3,166.3

[1]Totals may not agree due to rounding.

Table 4.—U.S. scallop imports, by region, 1980-85.

Region	Imports (1,000 t): 1980	1981	1982	1983	1984	1985
Lat. America	0.8	0.5	Negl.	1.3	2.0	5.5
N. America	6.9	8.7	6.8	6.3	3.9	5.4
Asia	0.1	0.4	0.5	3.6	3.4	5.1
Europe, W.	1.5	1.9	1.7	2.8	2.3	2.6
Oceania	0.2	0.5	0.4	1.8	0.7	0.5
Europe, E.						Negl.
Africa			Negl.	Negl.	Negl.	Negl.
Middle East						
Total[1]	9.5	11.9	9.5	15.5	12.4	19.1

[1]Totals may not agree due to rounding.

1,300 t in 1983 (Fig. 1). Shipments expanded rapidly and reached 5,500 t in 1985. The value of the 1985 shipments were $24 million, the fourth most important edible fishery product exported to the United States by Latin American countries. (Table 2).

Latin American scallop shipments continued to increase during the first half of 1986. Latin American shipments totaled 3,200 t, an increase of 30 percent from the 2,500 t exported during the same period of 1985 (Table 3). Declining Peruvian shipments were more than replaced by the sudden increase in shipments from Panama. Reports from both countries, however, suggest that shipments during the second half of 1986 were declining. As a result, 1986 year-end results from Latin America may not exceed 1985 levels.

The sharp fluctuations in scallop exports are not fully understood. Scallop catches, even in established fisheries, tend to fluctuate sharply. Sedentary shellfish species, like scallops, are subject to irregular recruitment patterns, often cyclical in nature. Climatic factors such as water temperatures can powerfully affect annual recruitment.

Scallop species are extremely fecund. One gravid female can produce anywhere from 2-20 million eggs. If ambient conditions are optimal, a small spawning stock can produce a large harvestable crop, sometines called a bloom. After a good set, intensive fishing effort, however, can shorten the duration of periods of high abundance and lengthen the period between successful sets.

Observers are not in total agreement over the development of the Peruvian fishery. Most biologists believe that the scallop stocks were affected by the 1982-83 El Niño event. The warmer El Niño water temperatures provided an ideal medium for the existing scallop stock and, at the same time, adversely affected many predators and competitors. Some biologists believe that there has always been a large scallop population off Peru, but that not only did the El Niño improve environmental conditions, the warmer water caused the scallops to successfully set in shallow water where they were more accessible to the fishermen. There may also be some migration of stocks, but this has not yet been demonstrated. A similar debate is now underway in Panama.

Regional Importance

Latin American countries emerged for the first time in 1985 as the most important source for U.S. scallop imports. U.S. imports from Latin America were 5,500 t, slightly more than the 5,400 imported from North American (Canada) and 5,100 t from Asian sources (Table 4). The U.S. imported a record 19,100 t of scallops worldwide in 1985, of that total nearly 30 percent were from Latin American countries. The economic importance, however, was less as the smaller Latin American species commanded a lower price on the U.S. market.

Species

Latin American fishermen catch small quantities of more than 10 different species of scallops (Table 1). The vast quantity of catches are composed of two species, the Peruvian calico scallop taken in Peru and Chile, and the Pacific calico scallop taken in Panama and other Central American countries. These two species and the other Latin American species are similar to the

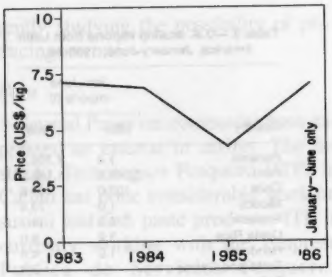

Figure 2.—U.S. import prices for Peruvian scallops, 1983-86.

Table 5.—U.S. scallop prices, by region, 1985.

Region	1985 Quantity (1,000 t)	1985 Value (US$ million)	1985 Price (US$/kg)
North America	5.4	58.7	10.87
Asia	5.1	44.4	8.70
Oceania	0.5	4.3	8.60
Western Europe	2.6	15.5	5.96
Latin America	5.5	24.0	4.36
Total[1]	9.5	147.1	6.46

[1]Totals may not agree due to rounding.

Table 6.—U.S. prices of scallops imported from Latin America, 1983-86.

Country	Prices (US$/kg) 1983	1984	1985	1986[1]
Argentina	9.88	6.41	5.88	8.94
Chile	8.30	7.47	6.47	7.23
Panama		9.57	5.11	5.89
Peru	7.13	6.84	4.24	7.02

[1]January to June.

Table 7.—U.S. scallop imports from Latin America by country, 1980-85.

Country	Imports (t) 1980	1981	1982	1983	1984	1985
Peru	4.5	4.4	Negl.	928.1	1,319.4	5,154.2
Chile			12.2	86.1	382.5	156.2
Argentina	2.4			192.5	285.3	136.9
Panama		26.1	3.9		1.4	41.0
Ecuador					5.5	8.9
Brazil	785.0	433.7	1.5	4.0		7.9
Mexico	5.4	15.2	13.6	122.3	20.5	6.1
Costa Rica	8.1					5.4
Honduras						2.9
Venezuela	2.0				0.6	1.9
Uruguay						1.5
Turks and Caicos					1.8	
Total[1]	807.5	479.4	31.2	1,333.0	2,017.2	5,522.9

[1]Totals may not agree due to rounding.

calico scallop, *A. gibbus*, taken off Florida. The meats are substantially smaller than those of the longer-lived cold water Atlantic sea scallop, *Placopecten magellanicus*, taken off the northeastern U.S. coast or imported from Canada.

Prices

Latin American scallops generally sell for substantially less on the U.S. market than scallops imported from other countries. In 1985, for example Latin American scallops sold for only about $4.35/kg, while North American and Asian scallops were selling for $10.90 and $8.70 per kilogram respectively (Table 5). The major reason for this difference is reportedly the small size of the Latin American scallops which are similar to the Florida calico scallops and follow the same market patterns. Peruvian observers also believe that intense competition among Peruvian exporters depressed prices. In 1986, the falling availability of the Peruvian scallops and the improving market conditions in the United States has resulted in a sharp price increase for the Peruvian product. Prices for Peruvian scallops averaged about $7.00/kg during the first 6 months of 1986 (Fig. 2, Table 6). The sharply increased production from Panama, however, has not shared the price increase achieved by Peruvian exporters, perhaps because the sudden increase in the catch has not allowed Panamanian exporters to develop adequate market channels for their newly acquired product. Panamanian scallops during the first 6 months of 1986 sold for only about $5.90/kg.

Major Countries

The Latin American scallop fisheries are dominated by Peru (Table 7). Peruvian shipments of 5,200 t accounted for 95 percent of the 5,500 t of Latin American scallops shipped to the United States in 1985. Panama reported significant shipments to the United States in early 1986. Brazil shipped sizeable quantities to the United States in 1980 and 1981, but current shipments are negligible. Several other countries (Chile, Argentina, and Mexico) have shipped small quantities to the United States. Shipments from other Latin American countries have been negligible. Recent developments in individual Latin American countries have been as follows.

Peru

Peruvian fishermen have conducted a scallop fishery since the pre-Columbian period. Archaeologists have discovered large deposits of shells dating back to 600 A.D. Catches in recent years have been small, averaging about 500 t per year. Fishermen began to report unusually large scallop catches after the El Niño event which devasted coastal areas in 1982 and 1983. One report, for example, estimated a phenomenal 1983 catch of nearly 20,000 t.

Biologists theorize that the warm water which appeared off the coast speeded scallop growth while it retarded the growth of competitors and predators. Competitors such as mussels, clams, crabs, limpets, Chilean abalone, and sea urchins were all adversely affected by the unusually warm El Niño water. Reproductive activity was apparently fostered by the warmer water temperatures and caused a higher survival rate among the resulting larvae. More larvae survived because the warmer water speeded their development rate, thus

Table 8.—U.S. scallop imports from Peru, by month 1983-86.

Month	Imports (t) 1983	1984	1985	1986
January		254.1	272.0	283.3[3]
February		246.8	318.3	599.0
March		248.5	497.5	236.6
April		100.2	301.9	43.1
May		76.5	344.7	20.7
June		101.6	631.1	6.4
July		16.8[2]	764.8	13.7[3]
August	6.9	3.2	507.5	N.A.[4]
September	66.3	4.7	633.5[5]	N.A.
October	179.9	19.6	691.0	N.A.
November	257.2	103.9	125.8[2]	N.A.
December	418.0	143.5	66.1	N.A.
Total[6]	928.1	1319.4	5,154.2	N.A.

[1]Fishing closed 11 January, originally until 14 May, but the closure was later extended. The closure was reportedly widely violated.
[2]Scallop season closed.
[3]The fishery was opened 15 July but at sharply reduced levels.
[4]Fishing was again closed August 31.
[5]Fishing restricted on 9 September.
[6]Totals may not agree to rounding.

reducing their vulnerability to predators and their chances of drifting away from the scallop banks where they could set.

A major scallop fishery soon developed in the Paracas area near Pisco along Peru's Central Coast. The scallops are harvested by artisanal divers from small boats. The Instituto del Mar (IMARPE) reports that over 1,000 small boats and 5,000 fishermen have entered the fishery. Another 6,000 people are employed on shore to process the catch. The unusually large catch in 1984 could not be handled by existing processing plants, so much work was done in makeshift plants or in the homes of the fishermen, initially giving rise to quality control problems. Improved processing was reported for the record 1985 catches when shipments to the United States exceeded 5,000 t (Table 8).

Some fishermen began to seed small scallops in the shallow areas of Paracas Bay. One report estimates that in 1984 there were 150 growers who had seeded 400 hectares of the Bay. Two groups are reportedly planning to build a hatchery. These culture efforts have met with mixed success. One massive kill in February 1985 was particularly damaging to the industry. The Government is concerned about declining catches and since March 1986 has closed the fishery, allowing only small artisanal catches. Most of the catch is marketed in the United States where only the adductor muscle (white meat) can be sold.

Exporters are also seeking European markets where the reproductive organs can be marketed along with the adductor muscle, substantially increasing the potential value of the catch. Peruvian 1986 shipments will be substantially below 1985 shipments. The Ministry of Fisheries closed the scallop fishery from January to June, but the regulations were widely violated. Many fishermen landed scallops, claiming they were cultured, which would exempt them from the closure. The fishermen were allowed to fish in July and August and reported good catches, mostly 40/60 and 60/80 count scallops. The sizes of the scallops caught in 1986 have been generally smaller than the scallops caught in 1986. The decline may be partially due to the intensive fishing effort, but larger populations of sea stars and saury as well as cooler water temperatures have also affected the scallop population. Unfished scallops populations have been found in deeper water. Peruvian scources reported the deaths of at least three divers in 1986, as the fishermen are diving in deeper water further from the coast. The Ministry closed the fishery again on 31 August 1986, for an indefinite period. IMARPE has begun a new project to repopulate grounds and is concentrating on banks to the north of Callao.

Panama

A major development in Panamanian fisheries during late 1985 and 1986 has been a sudden surge in scallop catches. Scallop fishing has been conducted by artisanal fishermen operating close to the coast for several years. Significant catches were reported in the 1960's, but Panamanian scallop exporters were not able to meet U.S. sanitary requirements. Since then, catches have been very small. Those fishermen began to report unusually good scallop catches in October 1985. Catches were particularly good in the Pacific coast area between Veracruz and Rio Hata, at depths from 3-20 m. In late 1985, some of the Panamanian companies, noting the artisanal fishing activity, began to deploy shrimp trawlers on the scallop beds. The Panamanian Government granted 13 licenses to shrimp trawlers. Catches surged to record levels.

Table 9.—U.S. scallop imports from Panama, 1981-86.

Month	Imports (t) 1981	1982	1984	1985	1986
January	9.8				84.5
February	10.5				157.6
March	3.8				284.2
April	1.9	0.2			282.2
May					405.7
June				1.4	491.2
July					344.1
August					N.A.[1]
September					N.A.[1]
October				1.5	N.A.
November		1.6	1.4	8.3	N.A.
December		0.8		29.8	N.A.
Total	26.1	3.9	1.4	41.0	2,049.5[2]

[1]Data not available, but imports reportedly continuing at high levels.
[2]Through July.

Panamanian catch data is not available, but most of the catch is exported to the United States. U.S. import data shows that imports are at record levels with shipments in June 1986 setting a single month record of 490 tons (Table 9). Shipments for the first 6 months of 1986 totaled 1,700 t valued at $10 million, with some of the product being airshipped to the United States. The commercial vessels are basd in Puerto Vacamonte and Rio Hato. Two plants have been opened at Vacamonte to process scallops.

Biologists are uncertain about the duration or reason for the scallops appearance off Panama. Some biologists see a 5 to 7 year cycle in which large populations periodically thrive and then decline. Others believe that a commercially exploitable stock is permanently there, but they only set in the more accessible shallow water when the environmental conditions are right. Commercial fishermen have noted scallops with considerable barnacle growth, however, suggesting that they may have been up to 2 years old at the time of harvest. The Director of the Panamanian Direccion General de Recursos Marinos, Armando Martinez, believes that temperature is the key factor determining abundance.

Panama first launched a scallop fishery in the 1960's when 15 shrimp trawlers were rigged for scallop fishing. The fishermen, however, could not find sustainable stocks on which to fish. Fishing has continued as a primarily artisanal activity, currently providing nearly 35,000 jobs. The current entry of the commercial fishermen has caused a major confrontation between the two groups. The artisanal fishermen, led by Napoleon Velasquez who is President of the Asociacion de Pescadores Artesanales (APROPA) has asked the government to restrict commercial fishing on coastal grounds where the artisanal fishermen harvest scallops. The only current restriction is one which prohibits commercial fishing within 3 miles of the coast.

Brazil

Brazil is the only other Latin American country to have conducted an important scallop fishery. The commercial fishery was launched in 1972 and Brazilian companies began to export in 1973. Two groups with Japanese backing were active in the preliminary stages of the fishery. Export shipments reached 450 t in 1974. The Brazilian scallop beds were located off the coast of Parana and Sao Paulo. Some Brazilian officials believed that scallop exports could eventually rival shrimp and lobster shipments, the mainstays of the country's fishing industry.

In 1981, U.S. scallop fishermen were brought in to conduct exploratory fishing for new grounds. The Brazilian fishery, however, has since dwindled. U.S. companies imported 785 t of scallops from Brazil in 1980, but this declined to only 435 t in 1981. Since 1982, U.S. importers have not purchased more than 10 t of scallops annually in Brazil. This drastic decline is unexplained. Local observers, however, believe that commercial stocks of scallops exist off Brazil and Caribbean countries, but will require more resource surveys to locate exploitable commercial beds. (Source: IFR-86/51.)

Australian Fishing, 1985

The Australian fishing industry contributed A$445 million (US$313 million) to the nation's GNP in 1985, making it the country's seventh largest rural industry. Australia's fishing industry is small (relative to the size of its fishing zone) and employs about 25,000 people in the harvest sector. Only about 10,000 fishing vessels are in operation and most are less than 20 m long. The Australian Government provides little or no subsidies or tariff protection to the fishing industry, so it has had to remain efficient in order to survive. Although the country's fishery resources are generally promising, Australia's traditional fisheries (shrimp, rock lobsters, scallops, abalone, bluefin tuna, and shark) are well developed with limited potential for future expansion. Growth of the fishing industry will be dependent on new fishing grounds and species. Northern fishing grounds hold promise for underexploited squid, skipjack and other tunas, and other pelagic fish resources.

Shrimp and rock lobsters are Australia's most important fishery exports, accounting for about 70 percent of the value of all fishery exports in 1985. Australia exported almost 6,000 metric tons (t) of shrimp, valued at A$91.3 million ($64.3 million), to major markets in Japan, the United States, and South Africa. Australia is also the world's largest producer of rock lobster, exporting 1,000 t valued at A$28.2 million ($19.9 million) in 1985. The United States is the major importer of this commodity, although Australia is also beginning to develop lobster export markets in Japan and Southeast Asia.

The U.S. Embassy in Australia has prepared a 12-page report on Australia's fishing industry in 1985. This report briefly reviews the Australian market, fisheries, and trade. Interested U.S. companies can obtain a copy of this report for $9.95 (personal check or money order) by ordering report number PB87-130258/AS from: National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. Please enclose a handling fee of $3.00 per order.

Ecuadorean Shrimp Culture

The marine shrimp culture industry has dramatically transformed much of the coast of southern Ecuador. Over 60,000 hectares of ponds have been built and both the ecology and the economy of the coast have been significantly altered. After 2 years of diminishing harvests, shrimp farmers are poised for production increases and higher earnings. Ecuadorean observers are predicting sharp increases in Ecuadorean 1987 shrimp exports made possible by the economic reforms instituted by the Ecuadorean Government in August 1986. Significantly increased production will require more postlarvae to stock the ponds. A postlarvae shortage severely affected farmed shrimp production in 1985, but postlarvae were in good supply during 1986. Government officials estimate that 24,500 metrict tons (t) of shrimp was exported in 1986 and project those shipments to increase to over 27,000 t in 1987, or by more than 10 percent.

The Foreign Commercial Service at the U.S. Consulate General in Guayaquil has prepared a 10-page report reviewing the current status of Ecuador's shrimp culture industry. The report covers the Ecuadorean Government economic reforms, shrimp production and exports, pond construction and operations, economic considerations, and hatcheries. The report also includes statistical tables. U.S. companies can obtain a copy of "Ecuadorean Shrimp Aquaculture Production, 1985-87" for $9.95 and a $3 handling fee (total $12.25, personal checks or money orders only) by ordering report PB87-139333/GBA from NTIS, Springfield, VA 22161.

On Surimi and Other Engineered Seafoods

The growth in popularity and production of certain engineered seafoods has been explored in articles in the Foreign Fisheries Developments section of this issue. Here, then, are two recent publication that provide more specific information on these important products.

"Surimi" by Sunee C. Sonu provides an in-depth look at the history and processes of surimi manufacture and the products made from surimi. Chapter 1 presents a historical perspective on surimi, including the importance of the Japanese surimi industry to the United States, the introduction of frozen surimi technology, automation of surimi production, production of ship-processed surimi, the surimi-based imitation seafood products, and surimi from underutilized species. Also covered is the Japanese surimi industry—its production, imports and exports, prices, products, and raw material resources.

Surimi manufacturing procedures for white-fleshed fishes are reviewed in Chapter 2, including the handling of the raw material, meat separation, leaching, straining and dewatering, additives used, and freezing and cold storage. Also covered is the surimi production plant itself. Chapter 3 discusses aspects of surimi based on dark-fleshed fishes—the technical problems involved (i.e., rapid protein deterioration and the large content of sarcoplasmic protein, dark muscle tissue, and fat) and the manufacturing procedures involved. Chapter 4, on surimi quality, then discusses quality standards, test procedures, and test results. The volume is based on an extensive review of the literature, conversations and interviews with experts, and studies of surimi plant operations and is a fine review, well illustrated with 56 diagrams, photos, and flowcharts. The 122-page paperbound report is NOAA Technical Memoradum NMFS-SWR-013 and is sold by the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

Also available now is the **"Proceedings of the International Symposium on Engineered Seafood Including Surimi,"** edited by Roy E. Martin and Robert L. Collette of the National Fisheries Institute (NFI) in Washington, D.C. The symposium was held 19-21 November 1985 in Seattle, Wash., and the 63 papers present a broad range of engineered food and surimi topics with worldwide application and interest.

Following the opening addresses are five papers on resource availability for engineered seafoods—prospects in developing nations for production of surimi products, New England resources, the menhaden resource, the case for Pacific whiting, *Merluccius productus*; and trends and abundance of walleye pollock off Alaska. Another session, moderated by Lloyd Regier and John Spinelli, addresses product and technology development of engineered seafoods: History of surimi and its products in Japan, fish as the "soybean of the sea"; using frozen minced fish, effect of cod fillet holding temperature on surimi; effect of washing on the composition and functional stability of minced pollock flesh; processing requirements for preparation of minced intermediates or surimi from menhaden; surimi from Pacific whiting; proximate analysis of surimi made from black drum; use of Norwegian industrial fishes for surimi; surimi from red hake, *Urophycis chuss*; nutrients and quality of surimi-based products; and more.

Also included is the special panel discussion moderated by Spinelli on emerging technologies for producing surimi. In another session, moderated by Roland Chambers, ten papers address national and international aspects of marketing and economics of surimi-based foods. Three other papers discuss various regulatory and institutional issues, including the labeling requirements for engineered seafoods.

Another lengthy session provided 13 contributions on the equipment and ingredients for engineered seafoods, and was moderated by Robert Collette. Presentations ranged from discussions of machinery needed for flesh-bone separation for various species to the packaging of products, effects of ingredients on gel texture, use of isolated soy protein and soluble milk protein hydrolysates, and flavorings for the products.

Later, an international roundtable moderated by James Brooker discussed surimi prospects in Australia and New Zealand, European studies and production, Nordic work with minced fish, Korean and Thailand surimi developments and resources, and surimi overviews by participants from Japan, Canada, and the United States. The volume also includes reprints of journal articles on "Developing appropriate nomenclature for structured seafood products" by Roy E. Martin and "Surimi process technology" by Chong M. Lee of the University of Rhode Island.

The paperbound, large-format publication is 732 pages long and collectively presents a sweeping overview of topics important to the expansion and utilization of several marine fisheries. It is available from the National Fisheries Educatic.. and Research Foundation, 2000 M Street, N.W., Suite 580, Washington, DC 20036 for $55.00.

Recent Studies in Fish Immunology

Publication of **"Fish Immunology,"** edited by Joanne S. Stolen, Douglas P. Anderson, and Willem B. van Muiswinkel, has been announced by Elsevier Science Publishers, P.O. Box 330, 1000 AH Amsterdam, The Netherlands. The volume contains the proceedings of an International Meeting of Fish Immunology held in Sandy Hook, N.J., 8-12 September 1985. Published first as volume 12 of *Veterinary Immunology and Immunopathology*, the papers are now available in a more durable and accessible hardbound form for advanced students and scientists.

Much progress has been made in the past decade in studies on fish immunology and in its practical applications. The results of such studies often have phylogenetic significance for veterinary and clinical immunologists, for scientists studying environmental and pollution problems, and for practicing fish farmers and fish culture researchers. This volume is a good source of information on basic immunological principles and on recent fish immunology studies, and the 47 scientific papers represent contributors from 18 different nations.

Like the conference, the volume is arranged by session, with contributions discussing aspects of: 1) Fish immunoglobulins, lymphocyte populations, MHC, nonspecific factors, and soluble substances; 2) lymphocyte and macrophage structure and function—ontogeny, lymphoid organs; 3) cellular and humoral respnses; 4) modulation of the immune response; and 5) immunity to disease agents.

Contributions include papers on using artificial gynogenesis in studying the carp immune system, immunological studies with channel catfish, carcharhinid sharks, and goldfish; modulation of nonspecific host defenses in fish, and studies on the alpha-precipitins of Atlantic salmon. Additional papers discuss the ontogeny of humoral immunity in rainbow trout, ontogeny of gut-associated lymphoid tissue in the dogfish *Scyliorhinus canicula*, lymphoid organs in sturgeons, immune response to PKD in rainbow trout, interactions of TCDD with immune responses of rainbow trout, pharmacokinetics of sulphadimidine in carp, and the seasonal antibody response in juvenile summer flounder to the hemoflagellate *Trypanoplasma bullocki*. Further contributions include work on the persistence of IPN virus in Atlantic salmon, immunosuppression of carp to ichthyophthiriasis using the corticosteroid triamcinolone acetonide, seasonal changes in the humoral immune response and the lymphoid tissues of *Sebasticus marmoratus*, immunization and culture of rainbow trout organ sections in vitro, and others.

In all, the contributions reflect many of the studies made in the field of fish immunology in recent years and will be a useful reference. The hardbound 443-page volume contains both author and subject indexes and costs Dfl 195.00; in the United States and Canada it is available from Elsevier Science Publishing Co., Inc., P.O. Box 1663, Grand Central Station, New York, NY 10163 for $72.25.

Bowhead Whaling in the Western Arctic

"Whales, Ice, & Men" by John R. Bockstoce, subtitled "The History of Whaling in the Western Arctic," has been published by the University of Washington Press, P.O. Box C-50096, Seattle, WA 98145-0096. The book is essentially a history of the western Arctic bowhead whaling industry, and an excellent one at that. By "western Arctic," Bockstoce refers to all of the waters of the Bering, Chukchi, and Beaufort Seas, but excluding Bristol Bay. The large-format volume is amply illustrated with 141 photographs, plus maps and drawings, and the author has done a fine job of placing the depletion of the bowhead whale there in perspective, both economically and historically. Bockstoce is curator of ethnology at the Old Dartmouth Historical Society Whaling Museum in New Bedford, Mass., and has made extensive studies of the region's whaling, to the extent of identifying the whaleships that cruised western Arctic waters year by year and documenting their kills as closely as possible—an immense task. Development of the book is also partly tied to the efforts to calculate historic levels of bowhead whale populations in recent years.

Chapters discuss the early development of the fishery (1849-64), Civil War strife in the Bering Strait, walrus hunting, whaling in the 1870's when almost 60 vessels were lost, trade with the natives, the advent of steam whaling, whaling from shore, wintering over at Herschel Island, Federal support for an Arctic whaling station, disastrous whaling fleet losses in 1897, and the decline of the fishery. Other chapters relate outfitting for the voyages, the pursuit and capture of the whales, the techniques and tools of whaling, etc. An Epilogue relates the fortunes of one C. T. Pedersen, whose vessel the *Herman* was the last to take a bowhead whale commercially, and who later turned to the Arctic fur trade.

Several appendices provide data on the chronology of major events in the western Arctic whale fishery, estimated annual and cumulative catch removal of bowhead whales and walruses from 1849 to 1914, a gazetteer of whalers' place names in the western Arctic, a glossary, and a graph of the prices of whale oil and baleen, CPUE, and number of whaleships in the fishery from 1848 to 1914. Also provided are a key to repository symbols where data was collected, pertinent chapter notes and references; extensive literature citations are listed by topic. The book is a fine and scholarly description of the times and trials of both the whalers and the bowhead whales which is often related through the words of the actual participants. Indexed, the 400-page hardbound volume costs $29.95.

THE BASICS OF FISH GENETICS

Publication of **"Genetics for Fish Hatchery Managers"** by Douglas Tave has been announced by AVI Publishing Company, Inc., 250 Post Road East, P.O. Box 831, Westport, CT 06881. The author is with the Department of Fisheries and Allied Aquacultures, Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama, and he presents the genetic aspects of animal breeding for fish farmers, hatchery managers, and others responsible for aquaculture programs in an easy-to-read and well illustrated format.

To the uninitiated, genetics may be viewed as exceedingly complicated. The author, however, has attempted to bridge the gap between the geneticist and the fish culturist by starting at square one and presenting the information as simply as possible. In addition, he explains how this knowledge can be used to improve fish stocks and their productivity. Another purpose of the book is to convince hatchery managers that produc-

tivity depends, to a great extent, on breeding practices and how a fish population is managed genetically.

Says the author, "Productivity cannot be optimized if the biological potential of the population is not optimized." In four chapters, the author introduces a review of basic genetics, genetics of qualitative phenotypes, genetics of quantitative phenotypes, and genetics of broodstock management—how to select and achieve a more productive and disease resistant stock of fish. Discussed also is broodstock management for gamefish to be stocked in natural bodies of water, for rare or endangered species in need of rescue, and for species used either as food fish or bait fish, as well as use of a control population to evaluate the genetic strain.

This is not a textbook on fish genetics and therefore it does not cover such topics as chromosomal manipulation, molecular genetics, cytogenetics, etc. Rather, it is a well written manual for the aquaculturist on how to manage his fish population's gene pool in order to improve productivity. Appendix A lists the scientific names of fishes cited in text and tables, Appendix B describes how to describe a quantitative phenotype, and a glossary defines the terms used in the text. Selected references are provided. Indexed, the 300-page hardbound volume is available from the publisher for $39.00.

Rockfish and Research

"Rockfish: A Focus for Research?," edited by Rosemary Amidei and published by the California Sea Grant College Program (Rep. T-CSGCP-015, 71 pages, paper), University of California, A-032, La Jolla, CA 92093, presents the portion of the proceedings of a CSGCP workshop held 3-4 April 1986 to review California's rockfish fisheries, their importance, and research needs. William Lenarz presented an overview of the fishery and a panel representing scientists, managers, and commercial fisheries interests discussed research needs, fishery development, management, and other aspects of the rockfish fisheries. Besides the general overview of the fishery and its needs, the publication also contains an extensive bibliography of published works on or relating to the Pacific coast rockfishes.

Marine Fungi and Their Biology

Publication of **"The Biology of Marine Fungi,"** edited by S. T. Moss, has been announded by Cambridge University Press, 32 East 57th Street, New York, NY 10022. The volume is based on invited papers presented at the Fourth International Marine Mycology Symposium convened at Portsmouth Polytechnic in the United Kingdom in August 1985.

Fungi are both important and ubiquitous members of the biota of marine ecosystems, and increased studies have been made into their role in the seas, their physiological adaptations, distribution, and economic importance (either as pathogens of plants or animals), and their ecological importance as degraders of organic materials. It has been some time since volumes have reviewed either the literature on marine fungi or the higher marine fungi or the literature on both the higher and lower forms of marine fungi. This volume, with experts reviewing the literature in their particular fields of expertise, is an excellent updated source of information; references are complete through 1985, and many authors have cited pertinent 1986 literature.

There are four main themes in the volume: Ecology, taxonomy, physiology, and industrial and applied biotechnology, and within them is treated a broad spectrum of subjects, including pathology of marine plants and animals, mycelial adhesion, biodeterioration, and conservation. Topics of several of the 30 papers in this volume include: Fungal growth in the sea, fungi and hydrocarbons in the marine environment, measuring fungal-biomass dynamics (in standing-dead leaves of a salt marsh vascular plant), growth and enzyme production in marine fungi, role of fungi in mangrove detrital systems, an overview of pathogenic fungi, progress of mycotic infections in marine animals, significance of fungal diseases in the marine environment, taxonomic studies of the marine Ascomycotina and Halosphaeriaceae, biogeography and the marine fingi, lignicolous marine fungi, timber decay caused by marine fingu and wood preservation, a preliminary account of Antarctic marine fungi, and others.

Contributors are internationally known experts whose papers will be valuable for advanced students of and researchers in mycology and marine biology. Overall, the volume provides an excellent account of the present state of the subject—the biology of both lower and higher marine and estuarine fungi. Indexed, the 382-page hardbound volume is available from the publisher for $49.50.

Biology, Fisheries, and Utilization of Sharks

"Sharks, An Inquiry into Biology, Behavior, Fisheries, and Use," edited by Sid Cook, has been published by the Oregon State University Extension Service, Corvallis, and is the proceedings of the conference of the same title held in Portland, Oreg., 13-15 October 1985.

Following brief introductory comments, Jose Castro presents an overview of the position of sharks in marine biological communities, and Gregor Cailliet reviews methods of estimating age and growth in sharks. In "Human Impacts on Shark Populations," Thomas B. Thorson reviews the effects of heavy fishing on the skate, school shark, bull shark, and the largetooth sawfish.

A lengthy review of shark behavior by Arthur Myrberg, Jr., is followed by psychologist Jon Magnuson's interesting examination of the history of the shark in human myths, legends, and rituals. Yet another angle is given on sharks and the news media by newsman Steve Boyer. Sid Cook has provided a lengthy review of the science of forensic shark attack investigations. (Also included are abstracts of talks on Pacific Coast shark attacks and on recent advances in protecting people from sharks.)

Other papers discuss U.S. shark fisheries, gear, and fishing methods; devel-

opment of a Pacific angel shark fishery in California, management of the southern California pelagic shark and swordfish fishery, development of Alaska's salmon shark fishery, proper handling and quality control of shark, shoreside processing of shark, developing specialty products from frozen shark, development considerations for a mid-Atlantic coast dogfish fishery, developing minced fish products from dogfish, a brief review of deep-sea shark fisheries (primarily Japanese), the growing use of shark in restaurants and in the home, and an overview of the development of U.S. shark sport fisheries which, in several areas, have soared in popularity. (Also included are abstracts on telemetering techniques to determine shark movement patterns.)

The Proceedings provide a very good overview of U.S. shark resources and the problems and prospects in their development, and the volume will be of considerable interest to anyone interested in or involved with sharks, their harvest and utilization. The 237-page paperbound volume is available from Agricultural Communications, Publications Orders, Oregon State University, Corvallis, OR 97331-2119 for $11.50 postpaid (make checks payable to Oregon State University).

Fish Stocks and Their Variability

"Dynamics of Marine Fish Populations" by Brian J. Rothchild has been published by Harvard University Press, Cambridge, Mass. The author, a former NMFS scientist, is Professor of Environmental and Estuarine Studies at the University of Maryland, and here he explores variability in the numerical abundance of fish populations and the reasons for it.

Chapter 1, an introductory discussion of variability in fish stock abundance, leads into examples in Chapter 2 of fish stock variability—an analysis of the historical record and a look at long- and short-term records. Chapter 3 reviews the unique properties of fish populations and discusses fishery-related population dynamics theory. Thus, the author provides a background on the nature of fish stock variability, examines the importance of understanding variations in fish stock abundance, and, in Chapter 4, establishes a structure for his subsequent analysis. Chapters 5-7 then examine nuances of the recruitment-stock relationship, egg production, and the fate of eggs and larvae in the sea, which sets the stage for the final chapter on implications of the population-dynamics process in which the author develops a foundation for his theory on fish stock variability.

The volume will likely be of interest to a fairly wide audience, including those concerned with the analysis of fish population variability, fish population dynamics, and others interested in the "evolution" of the population-dynamics-process model, etc. Hardbound, the 277-page volume is indexed, provides a lengthy list of references, and costs $37.50.

Surviving in Cold Water and Emergency Situations

NOAA-sponsored research into hypothermia problems has immensely helped make a dunking in chilly seawater far more survivable. And much of the resulting information is related in **"Hypothermia Causes, Effects, Prevention,"** by Robert S. Pozos and David O. Born, published by New Century Publishers, Inc., Piscataway, NJ. Pozos is Director of the Hypothermia and Water Safety Laboratory, University of Minnesota, Duluth, and a hypothermia authority, and David Born is a UM scientist and writer.

To date, much of the literature on hypothermia has been found in scientific reports or symposia or magazine articles. This excellent volume now makes it available for interested general readers, be they commercial fishermen, scientists, sport fishermen, survival instructors or whatever. It thoroughly describes the many factors that influence body temperature regulation, such as body composition, sex, race, physical handicaps, exercise, clothing, nutrition, and alcohol or drug use. In addition, the authors clearly explain the causes, effects and the prevention of hypothermia —the term for gradual chilling of the body's core and vital organs, especially the brain, heart, and lungs, to a level where the natural production of heat can no longer keep up with the heat losses. Hypothermia is especially of concern to those who have to work in cold environments or who face the possibility of immersion in cold water.

Besides giving excellent and thorough explanations of hypothermia, and how to avoid or prevent it and deal with it if it occurs, the authors also provide numerous medical and more popular survival references for further or more detailed reading. Other important chapters discuss frostbite, and rewarming, CPR, and field rescue for hypothermia victims. In addition, an important appendix by G. Patrick Lilja outlines the emergency treatment of both hypothermia and frostbite. Indexed, the 173-page hardbound volume costs $14.95.

A more comprehensive book on surviving outdoor emergencies is the **"Complete Book of Outdoor Survival"** by J. Wayne Fears, published by Outdoor Life Books and distributed by Stackpole Books, Cameron and Kelker Streets, P.O. Box 1831, Harrisburg, PA 17105. One of the largest books devoted purely to survival, this one covers a lot of material, some in considerable depth and some much less so. The book does have a lot of strong points, notably the many new and original illustrations that better explain survival points and particular survival techniques, etc. Its chapters on mental preparedness, the will to live, planning for the unexpected, and the search and rescue activities by the U.S. and Canadian Coast Guard units are also very good. Also useful is the material on survival medicine and safety, hypothermia, cold weather survival, firemaking, shelters, etc. The chapter on "Big Water Survival," however is very short and very basic, though it does cover signalling, marine communications, and the emergency position indicating radio beacon (EPIRB).

In addition, the author lists a variety of survival courses, some useful to fishermen, and three appendices cover 1) survival organizations 2) other books with specialized survival information, and 3) survival gear suppliers. The 484-page hardbound volume is indexed and costs $32.95.

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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